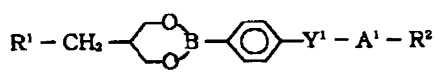
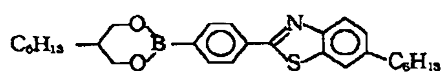
(Abstract)
(Amended)

Object
To put forward a liquid crystalline compound having rapid response rate and which is effective to reduce temperature dependency of the response rate, a liquid crystal composition containing the same, a liquid crystal element using the said liquid crystal composition and a display process and a display apparatus using them.

Construction
A liquid crystalline compound represented by the following general formula



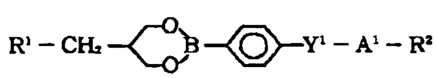
in an embodiment, for example



a liquid crystal composition containing at least one member of said liquid crystalline compounds, a liquid crystal element obtained by arranging the said liquid crystal composition between one pair of electrode base platess and a display process and a display apparatus using them.

Patent Claims

Claim 1
A liquid crystalline compound represented by following general formula (I)


(I)

(wherein in the said formula (I), R1 and R2 are straight chain form or branched chain form alkyl groups of carbon number 1-18, and 1 or 2 or more methylene groups in the said alkyl group may be substituted by

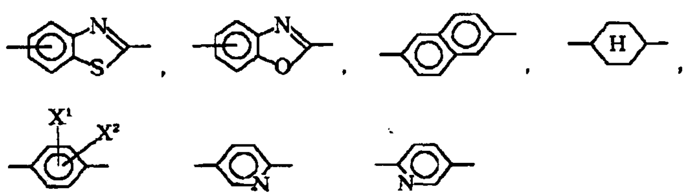
$$-O-,\quad -\underset{\underset{O}{\|}}{C}-,\quad -S-,\quad -CH=CH-,\quad -C\equiv C-,\quad -\overset{\overset{F}{|}}{C}H-$$

$$-\overset{\overset{CF_3}{|}}{C}H-,\quad -\overset{\overset{CN}{|}}{C}H-,\quad -\underset{\underset{CN}{|}}{\overset{\overset{CH_3}{|}}{C}}-$$

in the condition wherein heteroatoms are not adjacently positioned, and Y1 is selected from a single bond,

$$-\underset{\underset{O}{\|}}{C}O-,\quad -O\underset{\underset{O}{\|}}{C}-,\quad -CH_2O-,\quad -OCH_2-$$

and A1 is selected from

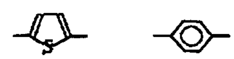


Wherein, X1, X2 are each independently selected from H, F, CF_3, CH3, CN, but X1 and X2 are not simultaneously H. Wherein when Y1 is a single bond,

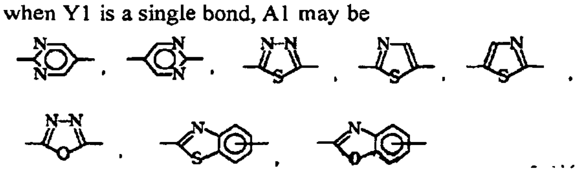
$$-O\underset{\underset{O}{\|}}{C}-,\quad -OCH_2-$$

,

A1 may be



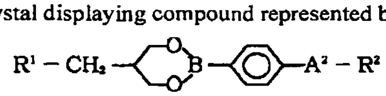
and moreover when Y1 is a single bond, A1 may be



- ...).

Claim 2

A liquid crystal displaying compound represented by the aforesaid general formula (Ia)



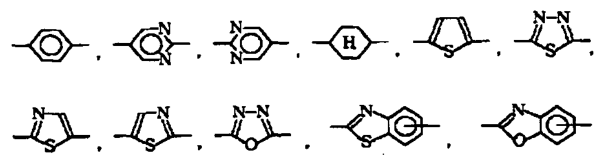
(I a)

(wherein in the said formula, R1 and R2 are straight chain form or branched chain form alkyl groups of carbon number 1-18, and 1 or 2 or more methylene groups in said alkyl group may be substituted by

$$-O-,\quad -\underset{\underset{O}{\|}}{C}-,\quad -S-,\quad -CH=CH-,\quad -C\equiv C-,\quad -\overset{\overset{F}{|}}{C}H-$$

$$-\overset{\overset{CF_3}{|}}{C}H-,\quad -\overset{\overset{CN}{|}}{C}H-,\quad -\overset{\overset{CH_3}{|}}{\underset{\underset{CN}{|}}{C}}-$$

in the condition wherein the heteroatoms are not adjacently positioned,
and A2 is selected from



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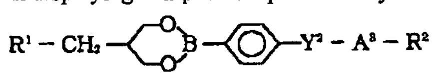
Claim 3

A liquid crystal displaying compound represented by the aforesaid general formula (Ib)



(I b)

(wherein in the said formulae, R1 and R2 are straight chain form or branched chain form alkyl groups of carbon number 1-18, and 1 or 2 or more methylene groups in said alkyl group may be substituted by

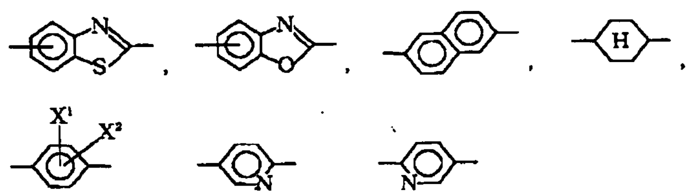
$$-O-,\quad -\underset{\underset{O}{\|}}{C}-,\quad -S-,\quad -CH=CH-,\quad -C\equiv C-,\quad -\overset{\overset{F}{|}}{C}H-$$

$$-\overset{\overset{CF_3}{|}}{C}H-,\quad -\overset{\overset{CN}{|}}{C}H-,\quad -\overset{\overset{CH_3}{|}}{\underset{\underset{CN}{|}}{C}}-$$

in the condition wherein heteroatoms are not adjacently positioned, and Y2 is selected from

$$-\underset{\underset{O}{\|}}{C}O-,\quad -O\underset{\underset{O}{\|}}{C}-,\quad -CH_2O-,\quad -OCH_2-$$

and A3 is selected from

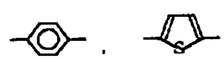


Wherein, X1, X2 are each independently selected from H, F, CF_3, CH3, CN, but X1 and X2 are not simultaneously H. Wherein when Y2 is

$$-\underset{\underset{O}{\|}}{OC}-, \quad -OCH_2-$$

,

A3 may be



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Claim 4

A liquid crystalline compound in accordance with Claim 1, wherein in compound represented by the aforesaid general formula (I), R1 is selected from the following (i)-(iii) and (v), and R2 is selected from (i)-(v).

(i) $-G^1-C_wH2_{w+1}-n$

(w is an integer of 1-17),

(ii)

$$-G^1-(CH_2)_m-\overset{\overset{CH_3}{|}}{C}H-C_nH_{2n+1}$$

(m is an integer of 0-7, and n is an integer of 1-9. Moreover, it may be optically active),

(iii)

$$-G^1-(CH_2)_r-\overset{\overset{CH_3}{|}}{C}H-(CH_2)_s-O-C_tH_{2t+1}$$

(r is an integer of 0-7, s is 0 or 1, and t is an integer of 1-14. Moreover, it may be optically active),

(iv)

$$-G^2-CH_2\overset{\overset{F}{|}}{C}HC_uH_{2u+1}$$

(u is an integer of 1-16 and it may be optically active) and

(v)

$$-G^1-(CH_2)_p-\overset{\overset{CF_3}{|}}{C}HC_qH_{2q+1}$$

(p is 1 or 2, and q is an integer of 1-14. Moreover, it may be optically active).
Wherein, G1 denotes a single bond,

$$-O-,\quad -\underset{\underset{O}{\|}}{C}O-,\quad -O\underset{\underset{O}{\|}}{C}-$$

and G2 is -O- or

$$-\underset{\underset{O}{\|}}{C}O-$$

Claim 5

A liquid crystalline compound in accordance with Claim 2, wherein in compound represented by the aforesaid general formula (Ia), R1 is selected from the following (i)-(iii) and (v), and R2 is selected from (i)-(v).

(i) $-G^1-C_wH2_{w+1}$-n
(w is an integer of 1-17),

(ii)

$$-G^1\!\!-\!\!\left(CH_2\right)_m\underset{}{\overset{\overset{CH_3}{|}}{C}}H-C_nH_{2n+1}$$

(m is an integer of 0-7, and n is an integer of 1-9. Moreover, it may be optically active),

(iii)

$$-G^1\!\!-\!\!\left(CH_2\right)_r\overset{\overset{CH_3}{|}}{C}H\!\!-\!\!\left(CH_2\right)_s O-C_tH_{2t+1}$$

(r is an integer of 0-7, s is 0 or 1, and t is an integer of 1-14. Moreover, it may be optically active),

(iv)

$$-G^2-CH_2\overset{\overset{F}{|}}{C}HC_uH_{2u+1}$$

(u is an integer of 1-16 and it may be optically active) and

(v)

$$-G^1\!\!-\!\!\left(CH_2\right)_p\overset{\overset{CF_3}{|}}{C}HC_qH_{2q+1}$$

(p is 1 or 2, and q is an integer of 1-14. Moreover, it may be optically active).
Wherein, G1 denotes a single bond,

$$-O-,\quad -\underset{\underset{O}{\|}}{C}O-,\quad -O\underset{\underset{O}{\|}}{C}-$$

and G2 is -O- or

$$-\underset{\underset{O}{\|}}{C}O-$$

Claim 6

A liquid crystalline compound in accordance with Claim 3, wherein in compound represented by the aforesaid general formula (Ib), R1 is selected from the following (i)-(iii) and (v), and R2 is selected from (i)-(v).

(i) $-G^1-C_wH2_{w+1}-n$
(w is an integer of 1-17),

(ii)
$$-G^1 \leftarrow CH_2 \rightarrow_m \underset{}{\overset{CH_3}{\overset{|}{C}}}H - C_nH_{2n+1}$$
(m is an integer of 0-7, and n is an integer of 1-9. Moreover, it may be optically active),

(iii)
$$-G^1 \leftarrow CH_2 \rightarrow_r \overset{CH_3}{\overset{|}{C}}H \leftarrow CH_2 \rightarrow_s O - C_tH_{2t+1}$$
(r is an integer of 0-7, s is 0 or 1, and t is an integer of 1-14. Moreover, it may be optically active),

(iv)
$$-G^2 - CH_2\overset{F}{\overset{|}{C}}HC_uH_{2u+1}$$
(u is an integer of 1-16 and it may be optically active) and

(v)
$$-G^1 \leftarrow CH_2 \rightarrow_p \overset{CF_3}{\overset{|}{C}}HC_qH_{2q+1}$$
(p is 1 or 2, and q is an integer of 1-14. Moreover, it may be optically active).
Wherein, G1 denotes a single bond,
$$-O-,\quad -\underset{\underset{O}{\|}}{C}O-,\quad -O\underset{\underset{O}{\|}}{C}-$$
and G2 is -O- or
$$-\underset{\underset{O}{\|}}{C}O-$$

Claim 7

A liquid crystal composition characterised by containing at least one liquid crystalline compound in accordance with Claim 1.

Claim 8

A liquid crystal composition in accordance with Claim 7 characterised by containing the liquid crystalline compound represented by general formula (I) in 1-80 wt.% with respect to the aforesaid liquid crystal composition.

Claim 9

A liquid crystal composition in accordance with Claim 7 characterised by containing the liquid crystalline compound represented by general formula (I) in 1-60 wt.% with respect to the aforesaid liquid crystal composition.

Claim 10

A liquid crystal composition in accordance with Claim 7 characterised by containing the liquid crystalline compound represented by general formula (I) in 1-40 wt.% with respect to the aforesaid liquid crystal composition.

Claim 11

A liquid crystal composition in accordance with Claim 7, wherein the aforesaid liquid crystal composition has chiral smectic phase.

Claim 12

A liquid crystal element characterised by arranging liquid crystal composition in accordance with Claim 7 between one pair of electrode base plates.

Claim 13

A liquid crystal element in accordance with Claim 12, wherein the orientation controlling layer is provided on the aforesaid electrode base plates.

Claim 14

A liquid crystal element in accordance with Claim 13, wherein the aforesaid orientation controlling layer is layer which is rubbing treated.

Claim 15

A liquid crystal element in accordance with Claim 12, wherein the aforesaid pair of electrode base plates are arranged with film thickness in which the spiral formed by arrangement of liquid crystal molecules is removed.

Claim 16

A display apparatus having liquid crystal element in accordance with the aforesaid Claim 12.

Claim 17

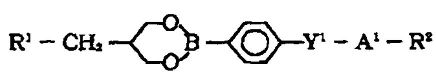
A display apparatus in accordance with Claim 16 further having drive circuit of liquid crystal element.

Claim 18

A display apparatus in accordance with Claim 16 further having light source.

Claim 19

A display process using a liquid crystal composition containing at least one member of liquid crystalline compound represented by following general formula (I)



(I)

(wherein in the said formulae (I), R1 and R2 are straight chain form or branched chain form alkyl groups of carbon number 1-18, and 1 or 2 or more methylene groups in said alkyl group may be substituted by

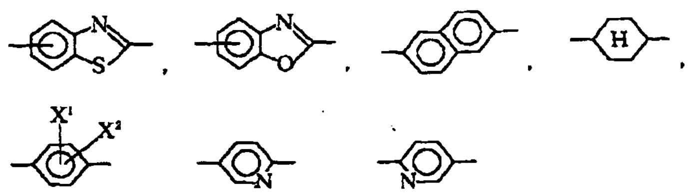
$$-O-,\quad -\underset{\underset{O}{\|}}{C}-,\quad -S-,\quad -CH=CH-,\quad -C\equiv C-,\quad -\overset{\overset{F}{|}}{C}H-$$

$$-\overset{\overset{CF_3}{|}}{C}H-,\quad -\overset{\overset{CN}{|}}{C}H-,\quad -\underset{\underset{CN}{|}}{\overset{\overset{CH_3}{|}}{C}}-$$

in the condition wherein heteroatoms are not adjacently positioned, and Y1 is selected from the single bond,

$$-\underset{\underset{O}{\|}}{C}O-,\quad -O\underset{\underset{O}{\|}}{C}-,\quad -CH_2O-,\quad -OCH_2-$$

and A1 is selected from

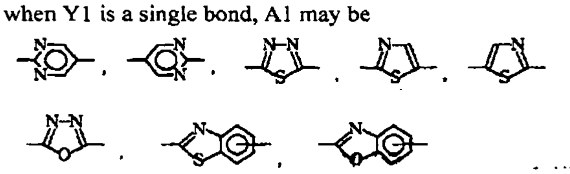


Wherein, X1, X2 are each independently selected from H, F, CF_3, CH3, CN, but X1 and X2 are not simultaneously H. Wherein when Y1 is a single bond,

$$-\underset{\substack{\|\\ O}}{OC}-,\qquad -OCH_2-$$

A1 may be

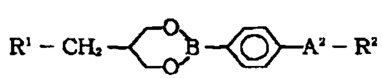
and moreover when Y1 is a single bond, A1 may be



. ....).

Claim 20

A display process using a liquid crystal composition containing at least one member of liquid crystalline compound represented by following general formula (Ia).



(I a)

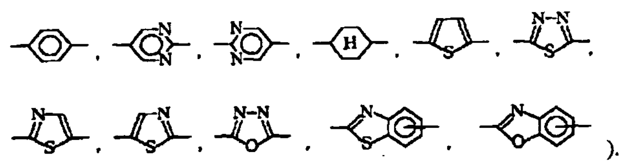
(wherein in the said formula, R1 and R2 are straight chain form or branched chain form alkyl groups of carbon number 1-18, and 1 or 2 or more methylene groups in said alkyl group may be substituted by .

$$-O-,\quad -\underset{\substack{\|\\ O}}{C}-,\quad -S-,\quad -CH=CH-,\quad -C\equiv C-,\quad -\overset{\substack{F\\ |}}{C}H-$$

$$-\overset{\substack{CF_3\\ |}}{C}H-,\quad -\overset{\substack{CN\\ |}}{C}H-,\quad -\underset{\substack{|\\ CN}}{\overset{\substack{CH_3\\ |}}{C}}-$$

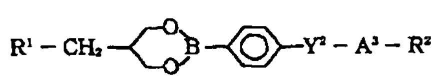
in the condition wherein heteroatoms are not adjacently positioned,

and A2 is selected from



Claim 21

A display process using a liquid crystal composition containing at least one member of liquid crystalline compound represented by following general formula (Ib)



(I b)

(wherein in the said formulae, R1 and R2 are straight chain form or branched chain form alkyl groups of carbon number 1-18, and 1 or 2 or more methylene groups in said alkyl group may be substituted by

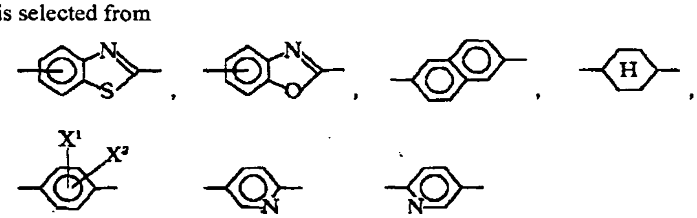
$$-O-,\quad -\underset{\underset{O}{\|}}{C}-,\quad -S-,\quad -CH=CH-,\quad -C\equiv C-,\quad -\overset{\overset{F}{|}}{C}H-$$

$$-\overset{\overset{CF_3}{|}}{C}H-,\quad -\overset{\overset{CN}{|}}{C}H-,\quad -\overset{\overset{CH_3}{|}}{\underset{\underset{CN}{|}}{C}}-$$

in the condition wherein heteroatoms are not adjacently positioned, and Y2 is selected from

$$-\underset{\underset{O}{\|}}{C}O-,\quad -O\underset{\underset{O}{\|}}{C}-,\quad -CH_2O-,\quad -OCH_2-$$

and A3 is selected from

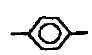
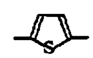


Wherein, X1, X2 are each independently selected from H, F, CF_3, CH3, CN, but X1 and X2 are not simultaneously H. Wherein when Y2 is

$$-\underset{\underset{O}{\|}}{OC}-, \quad -OCH_2-$$

,

A3 may be

 , ).

Claim 22

A display process in accordance with Claim 19, wherein in compound represented by the aforesaid general formula (I), R1 is selected from the following (i)-(iii) and (v), and R2 is selected from (i)-(v).

(i) $-G^1-C_wH2_{w+1}$-n

(w is an integer of 1-17),

(ii)

$$-G^1-(CH_2)_m-\overset{\overset{CH_3}{|}}{CH}-C_nH_{2n+1}$$

(m is an integer of 0-7, and n is an integer of 1-9. Moreover, it may be optically active),

(iii)

$$-G^1-(CH_2)_r-\overset{\overset{CH_3}{|}}{CH}-(CH_2)_s-O-C_tH_{2t+1}$$

(r is an integer of 0-7, s is 0 or 1, and t is an integer of 1-14. Moreover, it may be optically active),

(iv)

$$-G^2-CH_2\overset{\overset{F}{|}}{C}HC_uH_{2u+1}$$

(u is an integer of 1-16 and it may be optically active) and

(v)

$$-G^1-(CH_2)_p-\overset{\overset{CF_3}{|}}{C}HC_qH_{2q+1}$$

(p is 1 or 2, and q is an integer of 1-14. Moreover, it may be optically active).

Wherein, G1 denotes a single bond,

$$-O-, \quad -\underset{\underset{O}{\|}}{C}O-, \quad -O\underset{\underset{O}{\|}}{C}-$$

and G2 is -O- or

$$-\underset{\underset{O}{\|}}{C}O-$$

Claim 23

A display process in accordance with Claim 20, wherein in compound represented by the aforesaid general formula (Ia), R1 is selected from the following (i)-(iii) and (v), and R2 is selected from (i)-(v).

(i) $-G^1-C_wH2_{w+1}-n$
(w is an integer of 1-17),

(ii)
$$-G^1-(CH_2)_m-\underset{}{\overset{CH_3}{\overset{|}{C}}}H-C_nH_{2n+1}$$
(m is an integer of 0-7, and n is an integer of 1-9. Moreover, it may be optically active),

(iii)
$$-G^1-(CH_2)_r-\overset{CH_3}{\overset{|}{C}}H-(CH_2)_s-O-C_tH_{2t+1}$$
(r is an integer of 0-7, s is 0 or 1, and t is an integer of 1-14. Moreover, it may be optically active),

(iv)
$$-G^2-CH_2\overset{F}{\overset{|}{C}}HC_uH_{2u+1}$$
(u is an integer of 1-16 and it may be optically active) and

(v)
$$-G^1-(CH_2)_p-\overset{CF_3}{\overset{|}{C}}HC_qH_{2q+1}$$
(p is 1 or 2, and q is an integer of 1-14. Moreover, it may be optically active).
Wherein, G1 denotes a single bond,
$$-O-,\quad -\underset{\underset{O}{\|}}{C}O-,\quad -O\underset{\underset{O}{\|}}{C}-$$
and G2 is -O- or
$$-\underset{\underset{O}{\|}}{C}O-$$

Claim 24

A display process in accordance with Claim 21, wherein in compound represented by the aforesaid general formula (Ib), R1 is selected from the following (i)-(iii) and (v), and R2 is selected from (i)-(v).

(i) $-G^1-C_wH2_{w+1}-n$

(w is an integer of 1-17),

(ii)

$$-G^1 - (CH_2)_m - \overset{\displaystyle CH_3}{\overset{|}{C}}H - C_nH_{2n+1}$$

(m is an integer of 0-7, and n is an integer of 1-9. Moreover, it may be optically active),

(iii)

$$-G^1 - (CH_2)_r - \overset{\displaystyle CH_3}{\overset{|}{C}}H - (CH_2)_s - O - C_tH_{2t+1}$$

(r is an integer of 0-7, s is 0 or 1, and t is an integer of 1-14. Moreover, it may be optically active),

(iv)

$$-G^2 - CH_2\overset{\displaystyle F}{\overset{|}{C}}HC_uH_{2u+1}$$

(u is an integer of 1-16 and it may be optically active) and

(v)

$$-G^1 - (CH_2)_p - \overset{\displaystyle CF_3}{\overset{|}{C}}HC_qH_{2q+1}$$

(p is 1 or 2, and q is an integer of 1-14. Moreover, it may be optically active).

Wherein, G1 denotes a single bond,

$-O-$, $-\underset{\underset{\displaystyle O}{\|}}{C}O-$, $-O\underset{\underset{\displaystyle O}{\|}}{C}-$

and G2 is -O- or

$-\underset{\underset{\displaystyle O}{\|}}{C}O-$

Claim 24 (sic)

A display process in accordance with Claim 19 characterised by containing the liquid crystalline compound represented by general formula (I) in 1-80 wt.% with respect to the aforesaid liquid crystal composition.

Claim 25 (sic)

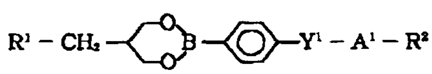
A display process in accordance with Claim 19 characterised by containing the liquid crystalline compound represented by general formula (I) in 1-60 wt.% with respect to the aforesaid liquid crystal composition.

Claim 26 (sic)
A display process in accordance with Claim 19 characterised by containing the liquid crystalline compound represented by general formula (I) in 1-40 wt.% with respect to the aforesaid liquid crystal composition.

Claim 27 (sic)
A display process in accordance with Claim 19, wherein the aforesaid liquid crystal composition has chiral smectic phase.

Claim 28 (sic)
A display process in accordance with Claim 27, wherein the display is carried out by electrically driving the aforesaid liquid crystal composition.

Claim 29 (sic)
A display process using a liquid crystal element obtained by arranging liquid crystal composition containing at least one member of liquid crystalline compound represented by following general formula (I) between one pair of electrode base plates.



(I)

(wherein in the said formulae (1), R1 and R2 are straight chain form or branched chain form alkyl groups of carbon number 1-18, and 1 or 2 or more methylene groups in said alkyl group may be substituted by

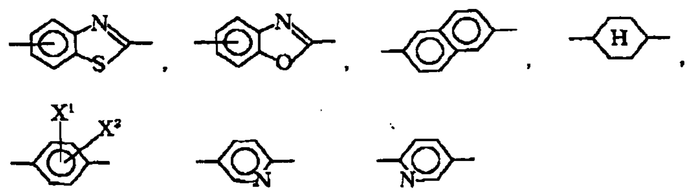
$$-O-,\quad -\underset{\underset{O}{\|}}{C}-,\quad -S-,\quad -CH=CH-,\quad -C\equiv C-,\quad -\overset{\overset{F}{|}}{C}H-$$

$$-\overset{\overset{CF_3}{|}}{C}H-,\quad -\overset{\overset{CN}{|}}{C}H-,\quad -\underset{\underset{CN}{|}}{\overset{\overset{CH_3}{|}}{C}}-$$

in the condition wherein heteroatoms are not adjacently positioned, and Y1 is selected from the single bond,

$$-\underset{\underset{O}{\|}}{C}O-,\quad -O\underset{\underset{O}{\|}}{C}-,\quad -CH_2O-,\quad -OCH_2-$$

and A1 is selected from



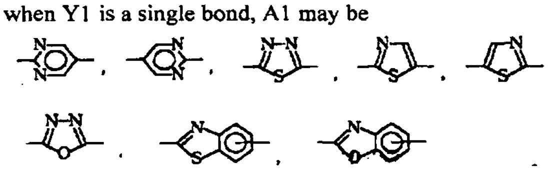
Wherein, X1, X2 are each independently selected from H, F, CF_3, CH3, CN, but X1 and X2 are not simultaneously H. Wherein when Y1 is a single bond,

$$-\underset{\underset{\text{O}}{\|}}{\text{OC}}-,\qquad -\text{OCH}_2-$$

,

A1 may be

and moreover when Y1 is a single bond, A1 may be



- ...).

Claim 30 (sic)

A display process in accordance with Claim 29, wherein the orientation controlling layer is further provided on the aforesaid electrode base plate.

Claim 31 (sic)

A display process in accordance with Claim 30, wherein the aforesaid orientation controlling layer is a rubbing-treated layer.

Claim 32 (sic)

A display process in accordance with Claim 29, wherein the aforesaid pair of electrode base plates are arranged with the film thickness in which the spiral formed by arrangement of liquid crystal molecules is removed.

Claim 33 (sic)

A display process in accordance with Claim 32, wherein the display is carried out by electrically driving the aforesaid liquid crystal composition.

Detailed Description of the Invention

(0001)

Sphere of Application in Industry

This invention relates to a novel liquid crystalline compound, a liquid crystal composition containing the same, a liquid crystal device and display unit using the same, more particularly, this invention relates to a novel liquid crystal composition with improved response character with respect to electric field, a liquid crystal device to be used as liquid crystal display device using the same, liquid crystal-light shutter and the like and a display unit using the said liquid crystal device for the display.

(0002)

Technology of the Prior Art

In the prior art, liquid crystal has been applied to various kinds of fields as electrical optic element. Presently, the most of the liquid crystal element put to practical application uses liquid crystal of TN (Twisted Nematic) type that was described for example by M. Schadt and W. Helfrich, Applied Physics Letters Vo.18, No.4, pp.127-128 (1971.2.15) "Voltage Dependent Optical Activity of a Twisted Nematic Liquid Crystal".

(0003)

These are based on the dielectric orientation effect of liquid crystal, and utilise the effect wherein the average molecular axis direction turns to specific direction due to an applied electric field as aresult of the dielectric anisotropy of liquid crystal molecules. The limit of optical response rate of these elements is said to be millisecond and is too slow for many applications. On the other hand, for the application in large-screen flat display, the drive using simple matrix system is the most effective on consideration of the price, productivity and the like. With the simple matrix system, an electrode construction in which the scanning electrode group and signal electrode group are constructed in a matrix form has been adopted, and, for the drive thereof, a time division drive system is adopted wherein the address signal is selectively applied periodically to the scanning electrode group, and the prescribed information signal is applied to the signal electrode group in parallel in synchronized manner with the address signal.

(0004)

However, when the aforesaid liquid crystal of TN type is used for the element of such drive system, a finite electic field will be applied to a region where the scanning electrode is selected but the signal electrode is not selected, or a region where the scanning

electrode is not selected but the signal electrode is selected (so-called "semi-selected point").

(0005)
When the difference between a voltage applied to a selected point and a voltage applied to a half-selected point is sufficiently large, then if the threshold voltage at which the molecules of a liquid crystal are oriented in the direction perpendicular to an electric field applied is between the above described voltages, the correct operation of a display element can be ensured. However, when the number (N) of scanning lines is increased, a time period (duty ratio) during which one selected point is subjected to an effective electric field during the time when the whole frame (one frame) is scanned is decreased at a ratio of 1/N.

(0006)
As a consequence, when repetitive scanning is performed, the greater the number of scanning lines, the smaller the effective voltage difference between a selected point and a non-selected point becomes. As a result, the problems of reduction in contrast of a picture and of crosstalk are unavoidable.

(0007)
These essentially unavoidable problems results when a driving method (that is, a repetitive scanning method) in which a liquid crystal which is not bistable (that is, a liquid crystal in which the molecules assume a stable state in which they are oriented in the horizontal direction relative to the surfaces of the electrodes and are oriented in the vertical direction only when an effective electric field is applied) is driven by utilizing a time storage effect.

(0008)
In order to overcome these problems, there have been proposed a voltage averaging method, a two-frequency driving, a multiple matrix method and so on. However, neither of these is satisfactory, and it is impossible at present to provide a display device with a large picture size and with a high density of picture elements because it is impossible to increase the number of scanning lines.

(0009)
As device that improves the shortcoming of such current liquid crystal element, the use of liquid crystal molecule having bistability is proposed by Clark and Lagerwall (Kokai 56-

107216, US Patent 4, 367, issue 924 specification or the like). As bistable liquid crystal, liquid crystal of chiral smectic C phase (SmC* phase) or H phase (SmH* phase) ferroelectricity is generally used.

(0010)

This ferroelectric liquid crystal has the bistable state comprising the first optically stable state with respect to electric field and the second optically stable state, and unlike the optical modulation element using the aforesaid TN type liquid crystal, for example, the liquid crystal is orientated in the first optically stable state with respect to one electric field vector, and the liquid crystal is orientated in the second optically stable state with respect to the other electric field vector. Moreover, liquid crystal of this type has the characteristic to assume either of the aforesaid two stable state in response to the electric field applied, and also to maintain the same state when there is no electric field (bistability).

(0011)

In addition to the character of having the aforesaid bistability, ferroelectric liquid crystal has an excellent character of high speed responsiveness. This is because the transition of orientation is induced by direct action between the spontaneous polarization of ferroelectric liquid crystal and the applied electric field, and it is 3-4 orders faster than the response rate due to the action of dielectric anisotropy and electric field.

(0012)

In this way, ferroelectric liquid crystal has extremely excellent character potentially, and most of problems of the said prior art TN type element can be essentially improved by using such properties. In particular, applications in high-speed optical light shutters and high density, large screen displays are anticipated. Therefore, studies have been widely carried out on liquid crystal material having ferroelectricity, however, it is hard to say that the ferroelectric liquid crystal materials developed to date have sufficient characteristics to be used as liquid crystal element including low temperature driving properties, high speed responsiveness.

(0013)

The relationship of the following equation [II] exists between the response time η, the size Ps of spontaneous polarization and viscosity η,

(0014)

(Equation 1).

$\eta = \eta/(Ps \cdot E)$ [II]

(wherein, E is applied electric field)

(0015)

Accordingly, in order to make response rate fast, there are processes

(a) to make the size Ps of spontaneous polarization greater,

(b) to make the viscosity η smaller, or

(c) to make the applied electric field E greater.

However, there is a upper limit for the applied electric field because of driving with IC, and it is preferably as low as possible. Accordingly, in practice, the viscosity η is made smaller or the value of size Ps of spontaneous polarization needs to be made greater.

(0016)

Generally, in the ferroelectric chiral smectic liquid crystal compound with a large spontaneous polarization, the internal electric field of the cell brought on by the spontaneous polarization is large, and restrictions to the element constitution that can have bistable state tends to increase. And even if the spontaneous polarization is made greater in vain, viscosity also tends to increase, and as a result, it is thought that the response rate is not increased much.

(0017)

Moreover, when the working temperature range, as real display is set for example at 5-40°C approx, generally there is around a 20 fold change in the response rate, and the present situation is that the change exceeds the limit of control using drive voltage and frequency.

(0018)

As described above, in order to put ferroelectric liquid crystal element to practical use, a liquid crystal composition showing chiral smectic phase with low viscosity, high speed response and small temperature dependency of response rate is demanded.

(0019)

Problems to be Overcome by this Invention

The object of this invention is to put forward the following, namely, in order to put the aforesaid ferroelectric liquid crystal element into practical use, to put forward a liquid

crystalline compound having fast response rate and in addition which is effective for reducing the temperature dependency of the response rate thereof, to put forward a liquid crystal composition containing the same, in particular a liquid crystal composition displaying ferroelectric chiral smectic phase, and a liquid crystal element using the said liquid crystal composition, a display process and a visual display using these.

(0020)

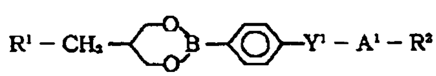
<u>Means to Overcome these Problems</u>

In other words, this invention is liquid crystalline compound represented by following general formula (I).

(0021)

General formula (I)

(0022)



(I)

(0023)

(wherein in the said formula (I), R1 and R2 are straight chain form or branched chain form alkyl groups of carbon number 1-18, and 1 or 2 or more methylene groups in the said alkyl group may be substituted by

(0024)

$$-O-,\quad -\underset{\underset{O}{\|}}{C}-,\quad -S-,\quad -CH=CH-,\quad -C\equiv C-,\quad -\overset{\overset{F}{|}}{C}H-$$

$$-\overset{\overset{CF_3}{|}}{C}H-,\quad -\overset{\overset{CN}{|}}{C}H-,\quad -\overset{\overset{CH_3}{|}}{\underset{\underset{CN}{|}}{C}}-$$

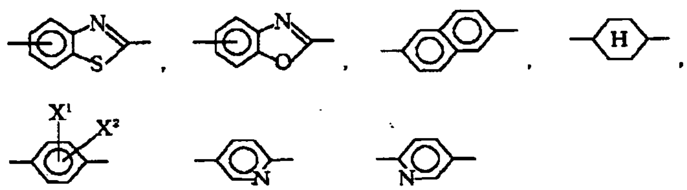
in the condition wherein heteroatoms are not adjacently positioned, and Y1 is selected from the single bond,

(0025)

$$-\underset{\underset{O}{\|}}{C}O-,\quad -O\underset{\underset{O}{\|}}{C}-,\quad -CH_2O-,\quad -OCH_2-$$

and A1 is selected from

(0026)



(0027)

Wherein, X1, X2 are each independently selected from H, F, CF_3, CH3, CN, but X1 and X2 are not simultaneously H. Wherein when Y1 is a single bond,

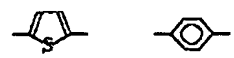
(0028)

$$-\underset{\underset{O}{\|}}{OC}-,\quad -OCH_2-$$

,

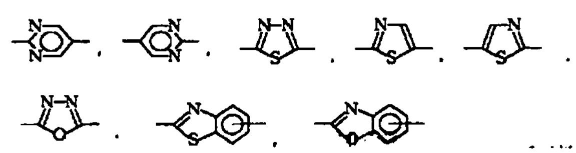
A1 may be

(0029)



and moreover when Y1 is a single bond, A1 may be

(0030)



. ...).

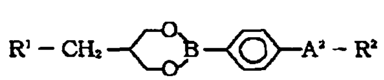
(0031)

Moreover, this invention puts forward a liquid crystal composition containing at least one member of said liquid crystalline compounds, a liquid crystal element obtained by arranging the said liquid crystal composition between one pair of electrode base platess and a display process and a display apparatus using them.

(0032)

Among the compounds represented by general formula (I), structures of preferred compounds are nominated as general formulae (Ia) and (Ib).

(0033)



(I a)

(0034)

(wherein in the said formula, R1 and R2 are straight chain form or branched chain form alkyl groups of carbon number 1-18, and 1 or 2 or more methylene groups in said alkyl group may be substituted by

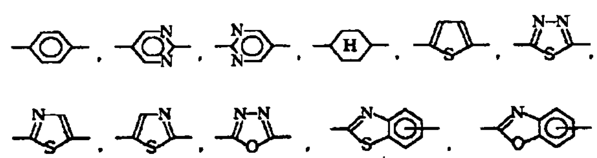
(0035)

$$-O-,\quad -\underset{\underset{O}{\|}}{C}-,\quad -S-,\quad -CH=CH-,\quad -C\equiv C-,\quad -\overset{\overset{F}{|}}{C}H-$$

$$-\overset{\overset{CF_3}{|}}{C}H-,\quad -\overset{\overset{CN}{|}}{C}H-,\quad -\overset{\overset{CH_3}{|}}{\underset{\underset{CN}{|}}{C}}-$$

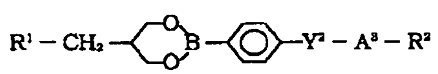
in the condition that the heteroatoms are not adjacently positioned, and A2 is selected from

(0036)



).

(0037)



(I b)

(0038)

(wherein in the said formula, R1 and R2 are straight chain form or branched chain form alkyl groups of carbon number 1-18, and 1 or 2 or more methylene groups in said alkyl group may be substituted by

(0039)

$$-O-,\quad -\underset{\underset{O}{\|}}{C}-,\quad -S-,\quad -CH=CH-,\quad -C\equiv C-,\quad -\overset{\overset{F}{|}}{C}H-$$

$$-\overset{\overset{CF_3}{|}}{C}H-,\quad -\overset{\overset{CN}{|}}{C}H-,\quad -\overset{\overset{CH_3}{|}}{\underset{\underset{CN}{|}}{C}}-$$

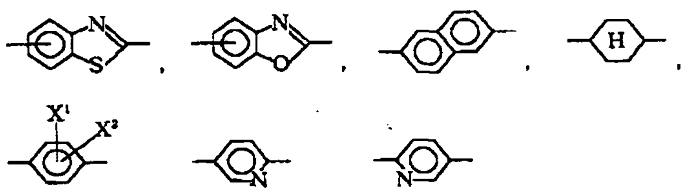
in the condition wherein heteroatoms are not adjacently positioned, and Y2 is selected from

(0040)

$$-\underset{\substack{\| \\ \mathrm{O}}}{\mathrm{C}}\mathrm{O}-,\quad -\mathrm{O}\underset{\substack{\| \\ \mathrm{O}}}{\mathrm{C}}-,\quad -\mathrm{CH_2O}-,\quad -\mathrm{OCH_2}-$$

and A3 is selected from

(0041)



(0042)

Wherein, X1, X2 are each independently selected from H, F, CF_3, CH3, CN, but X1 and X2 are not simultaneously H. Wherein when Y2 is

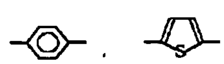
(0043)

$$-\mathrm{O}\underset{\substack{\| \\ \mathrm{O}}}{\mathrm{C}}-,\quad -\mathrm{OCH_2}-$$

,

A3 may be

(0044)



).

(0045)

More preferably, in the said general formulae (Ia) and (Ib), R1 is selected from the following (i)-(iii) and (v), and R2 is selected from (i)-(v).

(i) $-G^1-C_wH2_{w+1}$-n

(w is an integer of 1-17),

(0046)

(ii)

$$-G^1\!-\!\left(CH_2\right)_m\overset{\overset{CH_3}{|}}{C}H-C_nH_{2n+1}$$

(m is an integer of 0-7, and n is an integer of 1-9. Moreover, it may be optically active),

(0047)

(iii)

$$-G^1\!-\!\left(CH_2\right)_r\overset{\overset{CH_3}{|}}{C}H\!-\!\left(CH_2\right)_s O-C_tH_{2t+1}$$

(r is an integer of 0-7, s is 0 or 1, and t is an integer of 1-14. Moreover, it may be optically active),

(0048)

(iv)

$$-G^2-CH_2\overset{F}{\overset{|}{C}}HC_uH_{2u+1}$$

(u is an integer of 1-16 and it may be optically active) and

(0049)

(v)

$$-G^1-(CH_2)_p-\overset{CF_3}{\overset{|}{C}}HC_qH_{2q+1}$$

(p is 1 or 2, and q is an integer of 1-14. Moreover, it may be optically active).

(0050)

Wherein, G1 denotes a single bond,

$$-O-,\quad -\underset{\underset{O}{\|}}{C}O-,\quad -O\underset{\underset{O}{\|}}{C}-$$

and G2 is -O- or

$$-\underset{\underset{O}{\|}}{C}O-$$

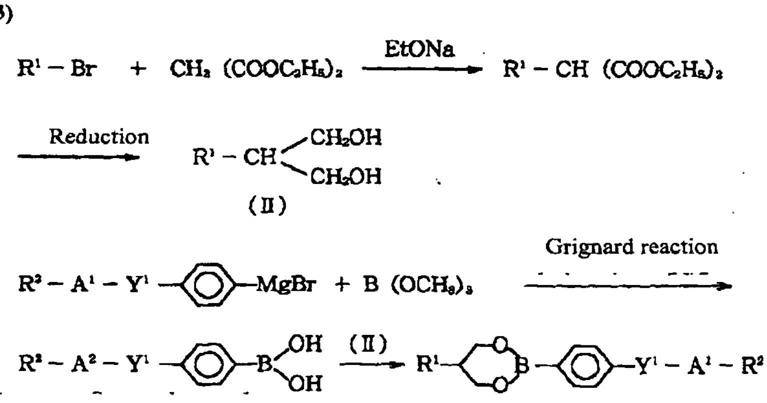
(0051)

These inventors discovered that, by using the aforesaid composition and the liquid crystal element using it, various characters such as temperature dependent of response rate or the like were improved and excellent display character was obtained.

(0052)

Hereinafter, this invention will be described in greater detail. General Synthesis Example of compound represented by the aforesaid general formula (I) is shown below.

(0053)



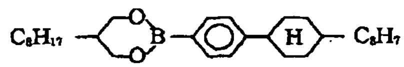
(0054)

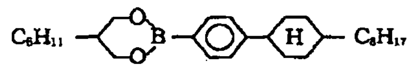
Moreover, it is also possible to introduce R1-A1-Y1- by eliminating the protecting group after Grignard reaction using raw material having the eliminatable protecting group instead of R2-A1-Y1-.

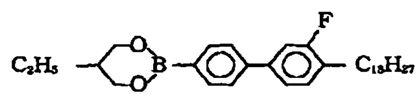
(0055)

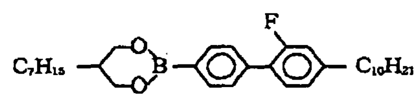
Examples of embodying structural formulae of liquid crystalline compounds represented by the aforesaid general formula (I) are shown below.

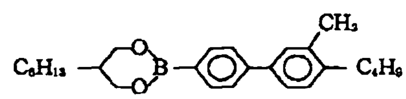
(0056)

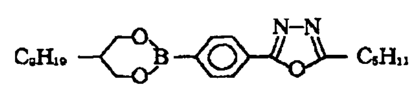
(I − 1)


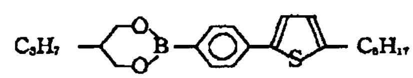
(I − 2)


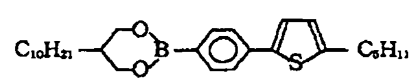
(I − 3)


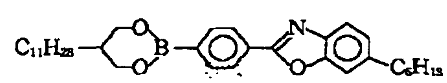
(I − 4)


(I − 5)


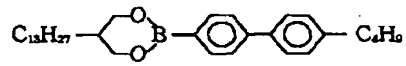
(I − 6)


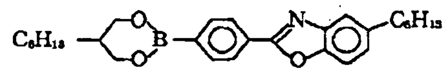
(I − 7)


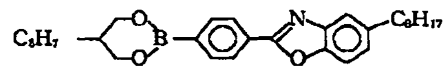
(I − 8)


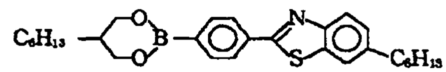
(I − 9)


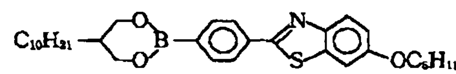
(0057)

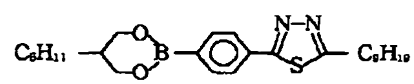
(I − 10)


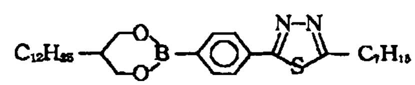
(I − 11)


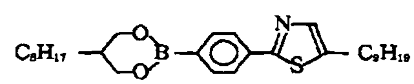
(I − 12)


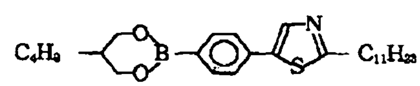
(I − 13)


(I − 14)


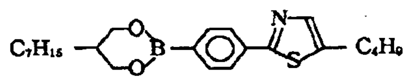
(I − 15)


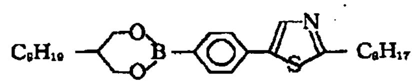
(I − 16)


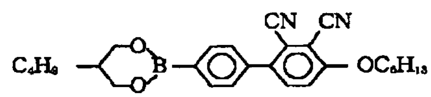
(I − 17)


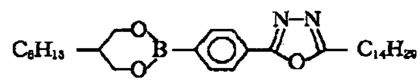
(I − 18)


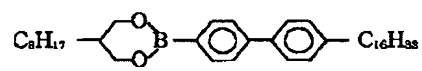
(0058)

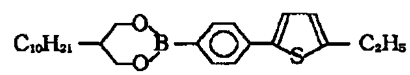
(I − 19) 

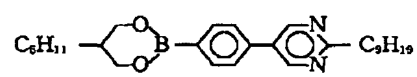
(I − 20) 

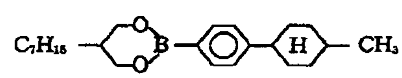
(I − 21) 

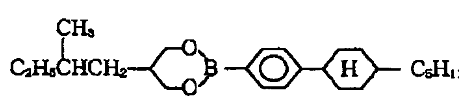
(I − 22) 

(I − 23) 

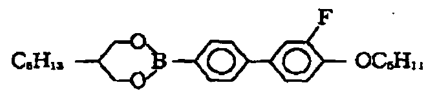
(I − 24) 

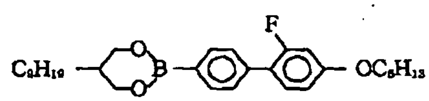
(I − 25) 

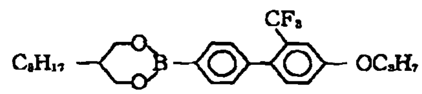
(I − 26) 

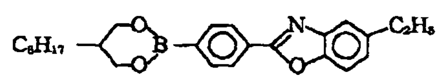
(I − 27) 

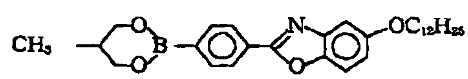
(0059)

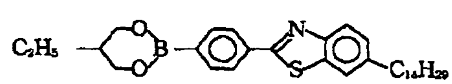
(I - 28) 

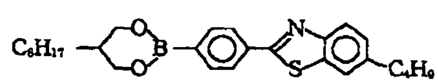
(I - 29) 

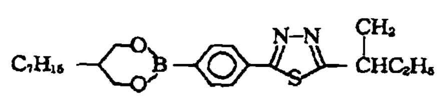
(I - 30) 

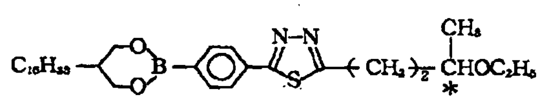
(I - 31) 

(I - 32) 

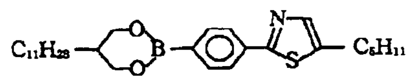
(I - 33) 

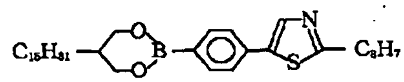
(I - 34) 

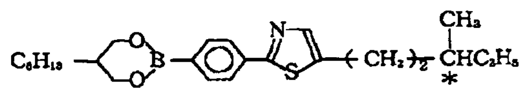
(I - 35) 

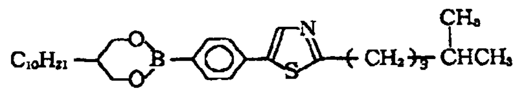
(I - 36) 

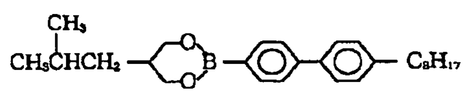
(0060)

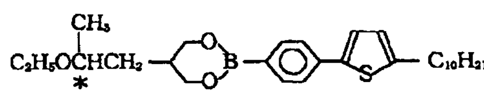
(I – 37) 

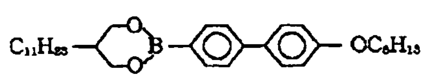
(I – 38) 

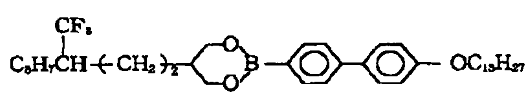
(I – 39) 

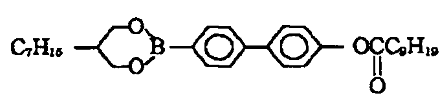
(I – 40) 

(I – 41) 

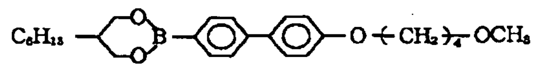
(I – 42) 

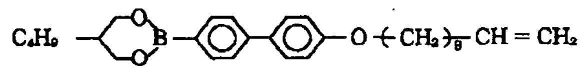
(I – 43) 

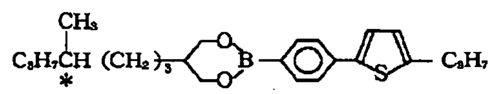
(I – 44) 

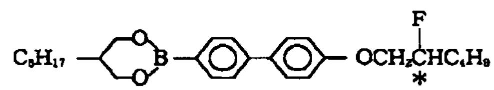
(I – 45) 

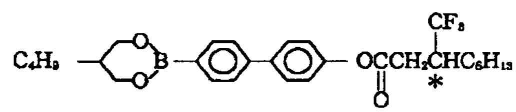
(0061)

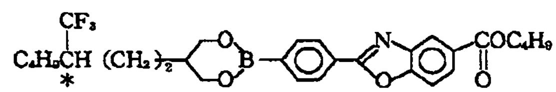
(I − 46) 

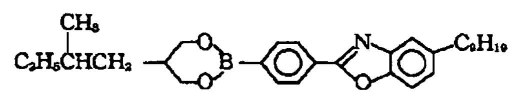
(I − 47) 

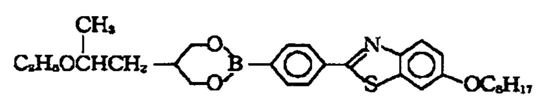
(I − 48) 

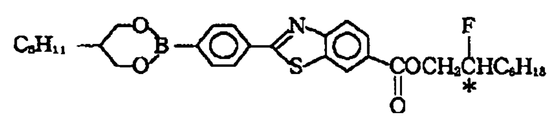
(I − 49) 

(I − 50) 

(I − 51) 

(I − 52) 

(I − 53) 

(I − 54) 

(0062)

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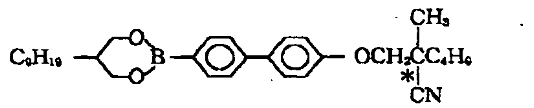

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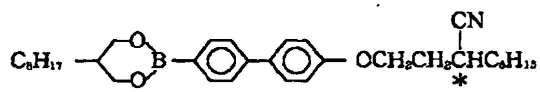

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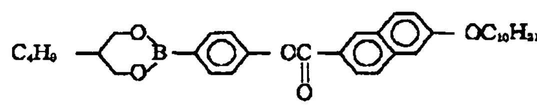

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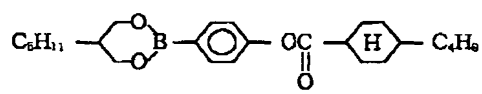

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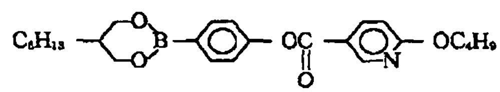

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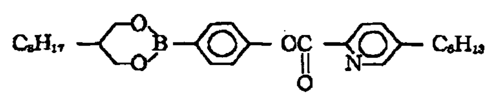

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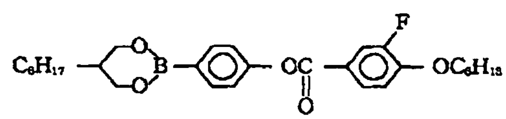

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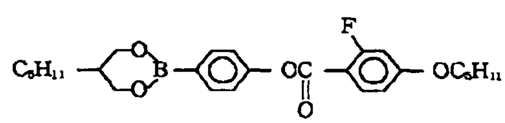

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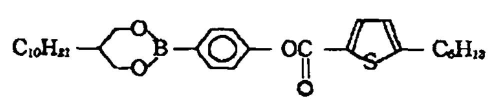
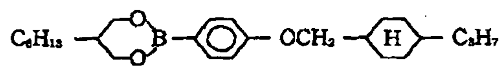
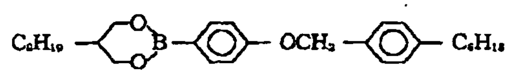
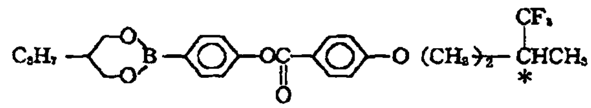
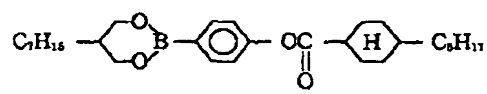


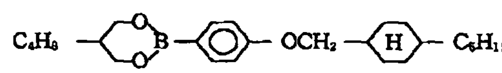
(0063)

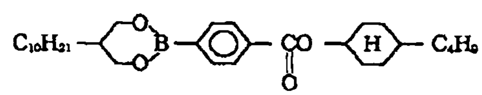
(I − 64) 

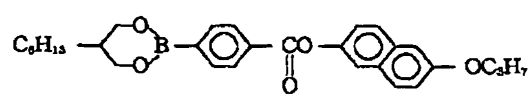
(I − 65) 

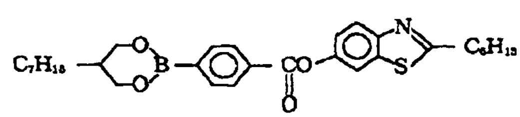
(I − 66) 

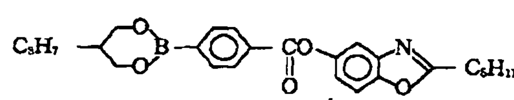
(I − 67) 

(I − 68) 

(I − 69) 

(I − 70) 

(I − 71) 

(I − 72) 

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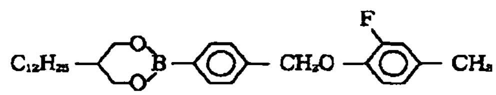
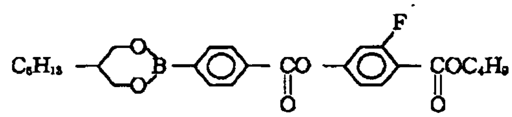
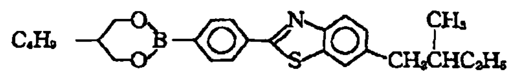
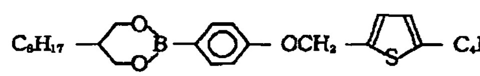
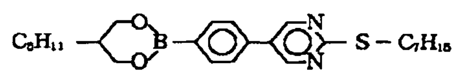
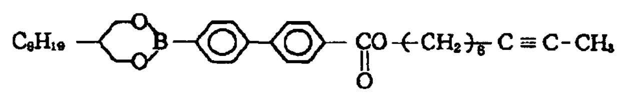
(I − 73) 

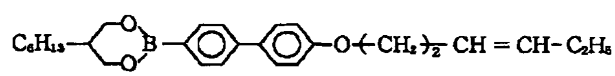
(I − 74) 

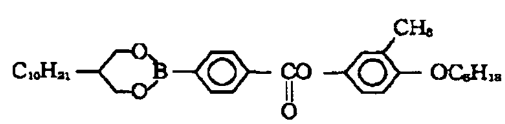
(I − 75) 

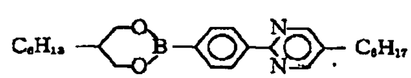
(I − 76) 

(I − 77) 

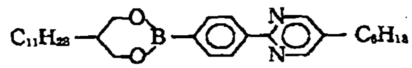
(I − 78) 

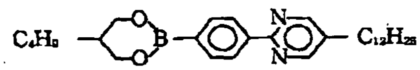
(I − 79) 

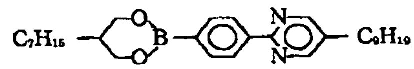
(I − 80) 

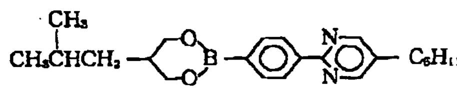
(I − 81) 

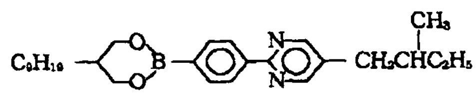
(0065)

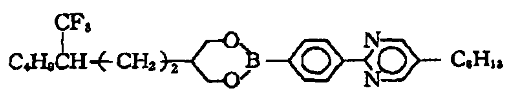
(I - 82) 

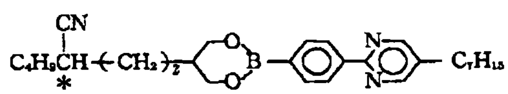
(I - 83) 

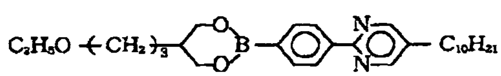
(I - 84) 

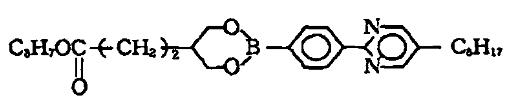
(I - 85) 

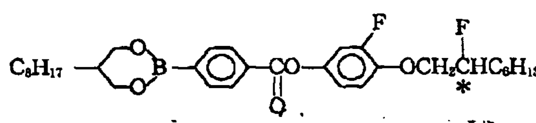
(I - 86) 

(I - 87) 

(I - 88) 

(I - 89) 

(I - 90) 

(I - 91) 

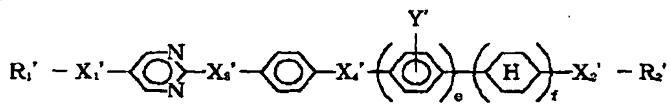
(0066)

Liquid crystal composition of this invention can be obtained by mixing at least one member of liquid crystalline compounds represented by the aforesaid general formula (I) and one or more member of other liquid crystalline compounds with suitable proportion. Moreover, the liquid crystal composition of this invention is preferably liquid crystal composition showing chiral smectic phase.

(0067)

The other liquid crystalline compounds used in this invention are shown below with general formulae (III)-(XIV).

(0068)



(III)

e: 0 or 1, f: 0 or 1, wherein e + f = 0 or 1.

Y': H, halogen, CH3, CF3

X1', X2': single bond,

$-\underset{\overset{\|}{O}}{C}O-$, $-O\underset{\overset{\|}{O}}{C}-$, $-O-$, $-O\underset{\overset{\|}{O}}{C}O-$

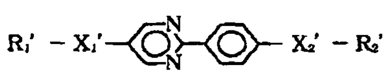
X3', X4': single bond,

$-\underset{\overset{\|}{O}}{C}O-$, $-O\underset{\overset{\|}{O}}{C}-$, $-OCH_2-$, $-CH_2O-$

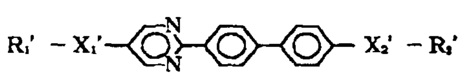
(0069)

(IIIa)-(IIId) are nominated as preferred compounds of formula (III).

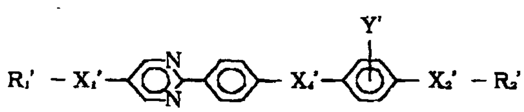
(0070)



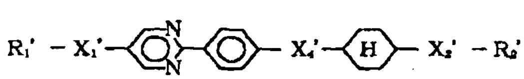
(III a)



(III b)

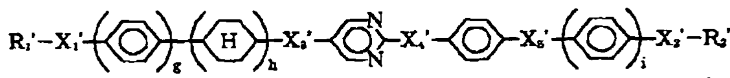


(III c)



(III d)

(0071)



(IV)

g, h: 0 or 1, wherein g + h = 1. i: 0 or 1

X1', X2': single bond,

$-\underset{\underset{O}{\|}}{C}O-$, $-O\underset{\underset{O}{\|}}{C}-$, , $-O-$, $-O\underset{\underset{O}{\|}}{C}O-$

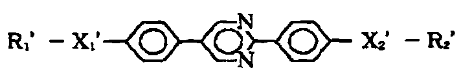
X3', X4', X5': single bond,

$-\underset{\underset{O}{\|}}{C}O-$, $-O\underset{\underset{O}{\|}}{C}-$, $-CH_2O-$, $-OCH_2-$

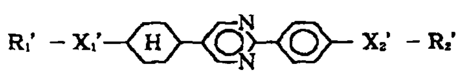
(0072)

(IVa)-(IVc) are nominated as preferred compounds of formula (IV).

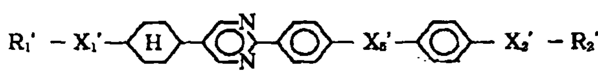
(0073)



(IV a)

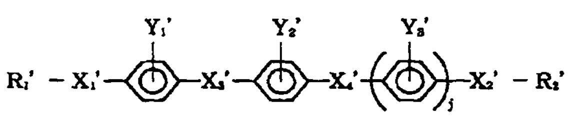


(IV b)



(IV c)

(0074)



(V)

J: 0 or 1

Y1', Y2', Y3': H, halogen, CH3, CF3

X1', X2': single bond,

$-\underset{\underset{O}{\|}}{C}O-$, $-O\underset{\underset{O}{\|}}{C}-$, , $-O-$, $-O\underset{\underset{O}{\|}}{C}O-$

X3', X4': single bond,

$$-\underset{\underset{O}{\|}}{C}O-,\ -O\underset{\underset{O}{\|}}{C}-,\ -CH_2O-,\ -OCH_2-,$$

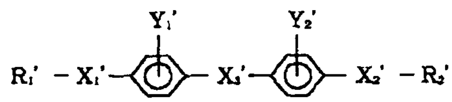
$$-CH_2CH_2-,\ -\underset{\underset{O}{\|}}{C}S-,\ -S\underset{\underset{O}{\|}}{C}-,\ -(CH_2)_2-\underset{\underset{O}{\|}}{C}S-,$$

$$-(CH_2)_2-\underset{\underset{O}{\|}}{C}O-,\ -CH=CH-\underset{\underset{O}{\|}}{C}O-,\ -O-$$

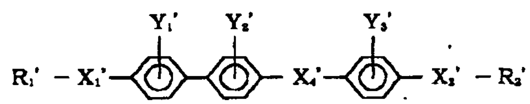
(0075)

(Va) and (Vb) are nominated as preferred compounds of formula (V).

(0076)

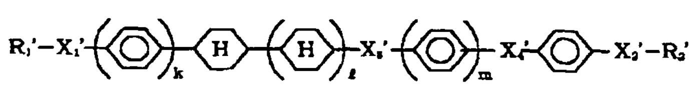


(V a)



(V b)

(0077)



(VI)

k, l, m: 0 or 1, wherein k + l + m = 0, 1, 2.

X1', X2': single bond,

$$-\underset{\underset{O}{\|}}{C}O-,\ -O\underset{\underset{O}{\|}}{C}-,\ -O-,\ -O\underset{\underset{O}{\|}}{C}O-$$

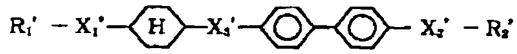
X3', X4': single bond,

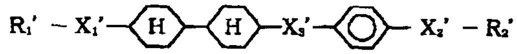
$$-\underset{\underset{O}{\|}}{C}O-,\ -O\underset{\underset{O}{\|}}{C}-,\ -CH_2O-,\ -OCH_2-$$

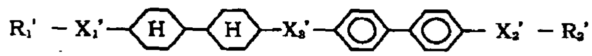
(0078)

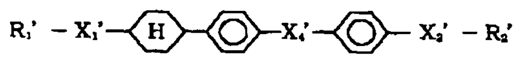
(VIa)-(VIf) are nominated as preferred compounds of formula (VI).

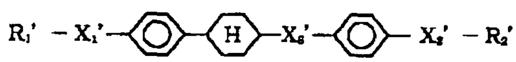
(0079)

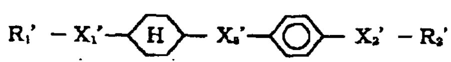

(VI a)


(VI b)


(VI c)


(VI d)


(VI e)


(VI f)

(0080)
Wherein, R1', R2' are straight chain form or branched chain form alkyl group of carbon number 1-18, and one or two or more $-CH_2-$ groups in the said alkyl group which are not adjacently positioned may be substituted by -CH halogen-. Moreover, one or two or more $-CH_2-$ groups except $-CH_2-$ group which is directly bonded with X1, X2 may be substituted by

(0081) (0082)

$$-O-,\quad -\underset{\Large O}{\overset{}{\underset{\|}{C}}}-,\quad -O\underset{\Large O}{\underset{\|}{C}}-,\quad -\underset{\Large O}{\underset{\|}{C}}O-,\quad -\overset{CF_3}{\overset{|}{C}}H-,\quad -\overset{CN}{\overset{|}{C}}H-,\quad -\overset{CN}{\overset{|}{C}}CH_3-$$

(0083)
Wherein when R1' or R2' is alkyl halide wherein one CH2 group is substituted by

(0084)

$$-\overset{CF_3}{\overset{|}{C}}H-$$

(0085)
or -CH halogen-, R1' or R2' is not bonded with single bond with respect to ring.

(0086)

Preferably R1', R2' are following i)-ix).

i) straight chain alkyl group of carbon number 1-15.

(0087)

ii)

$$-(CH_2)_p-\underset{}{C}H(CH_3)-C_qH_{2q+1}$$

p: integer of 0-5, q: integer of 2-11, it may be optical active.

(0088)

iii)

$$-(CH_2)_r-CH(CH_3)-(CH_2)_s-OC_tH_{2t+1}$$

r: integer of 0-6, s: integer of 0, 1, t: integer of 1-14, it may be optical active.

(0089)

iv)

$$-(CH_2)_u-\overset{*}{C}H(F)-C_vH_{2v+1}$$

u: integer of 0, 1, v: integer of 1-16.

(0090)

v)

$$-CH(CH_3)C(=O)OC_wH_{2w+1}$$

w: integer of 1-15, it may be optical active.

(0091)

vi)

$$-(CH_2)_x-\overset{*}{C}H(CF_3)-C_yH_{2y+1}$$

x: integer of 0-2, y: integer of 1-15.

(0092)

vii)

$$-\overset{*}{C}H(CF_3)CH_2C(=O)OC_zH_{2z+1}$$

z: integer of 1-15.

(0093)

viii)

$$-\!\left(CH_2\right)_A\!-\underset{}{\overset{\displaystyle CN}{\overset{|}{C}}}H\,C_BH_{2B+1}$$

A: integer of 0-2, B: integer of 1-15, it may be optical active.

(0094)

ix)

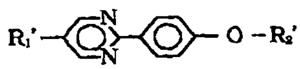
$$-\!\left(CH_2\right)_C\!-\overset{\displaystyle CN}{\overset{|}{\underset{\underset{\displaystyle CH_3}{|}}{C}}}-C_DH_{2D+1}$$

C: integer of 0-2, D: integer of 1-15, it may be optical active.

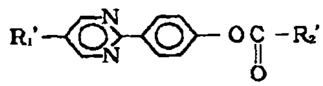
(0095)

(IIIaa)-(IIIdc) are nominated as more preferred compounds of (IIIa)-(IIId).

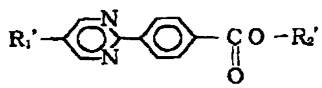
(0096)



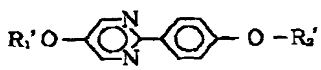
(Ⅲ aa)



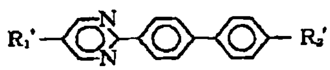
(Ⅲ ab)



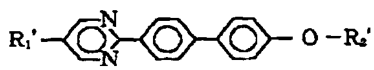
(Ⅲ ac)



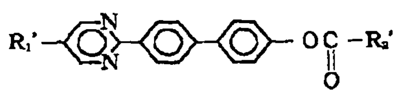
(Ⅲ ad)



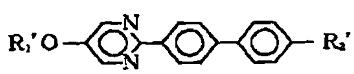
(Ⅲ ba)



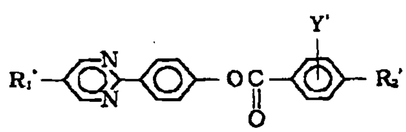
(Ⅲ bb)



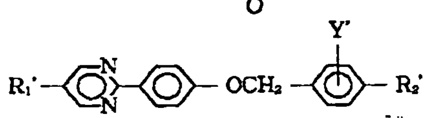
(Ⅲ bc)



(Ⅲ bd)

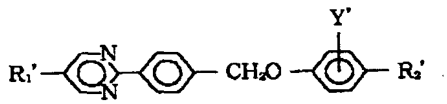


(Ⅲ ca)

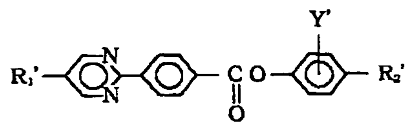


(Ⅲ cb)

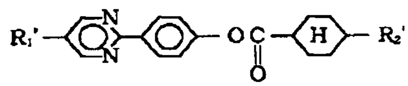
(0097)



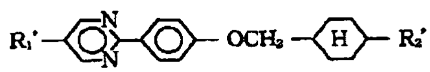
(III cc)



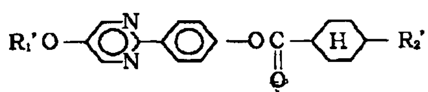
(III cd)



(III da)



(III db)

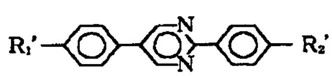


(III dc)

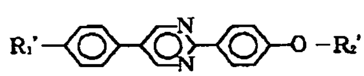
(0098)

(IVaa)-(IVcb) are nominated as more preferred compounds of (IVa)-(IVc).

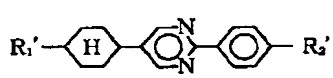
(0099)



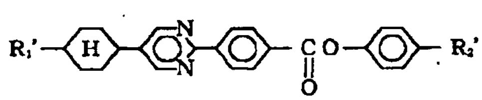
(IV aa)



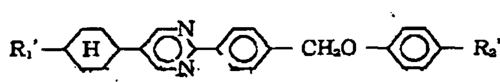
(IV ab)



(IV ba)



(IV ca)

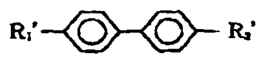


(IV cb)

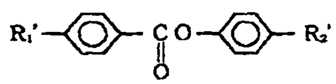
(0100)

(Vaa)-(Vdf) are nominated as more preferred compounds of (Va)-(Vd).

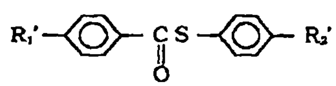
(0101)



(V aa)



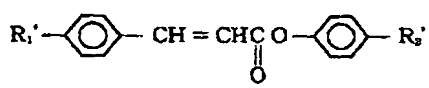
(V ab)



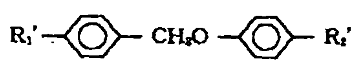
(V ac)

(V ad)

(V ae)

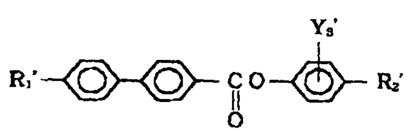


(V af)

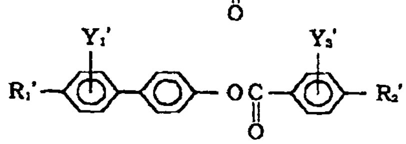


(V ag)

(V ah)

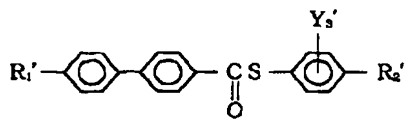


(V ba)

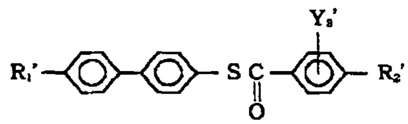


(V bb)

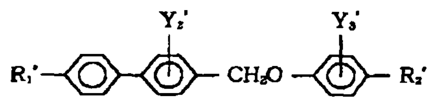
(0102)



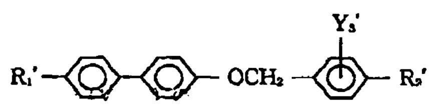
(V bc)



(V bd)



(V be)

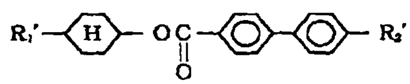


(V bf)

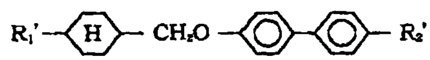
(0103)

(VIaa)-(VIfa) are nominated as more preferred compounds of (VIa)-(VIf).

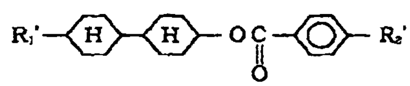
(0104)



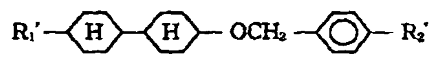
(VI aa)



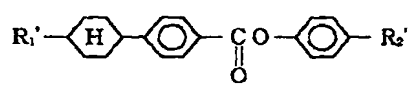
(VI ab)



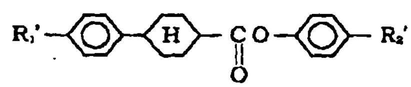
(VI ba)



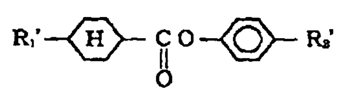
(VI bb)



(VI da)

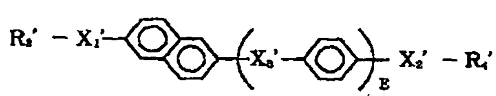


(VI ea)



(VI fa)

(0105)



(VII)

E: 0 or 1

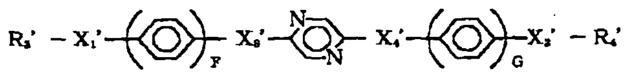
X1', X2': single bond,

$-\underset{\underset{O}{\|}}{C}O-$, $-O\underset{\underset{O}{\|}}{C}-$, $-O-$, $-O\underset{\underset{O}{\|}}{C}O-$

X3': single bond,

$-\underset{\underset{O}{\|}}{C}O-$, $-O\underset{\underset{O}{\|}}{C}-$, $-CH_2O-$, $-OCH_2-$

(0106)



(VIII)

F, G: 0 or 1

X1', X2': single bond,

$-\underset{\underset{O}{\|}}{C}O-$, $-O\underset{\underset{O}{\|}}{C}-$, $-O-$

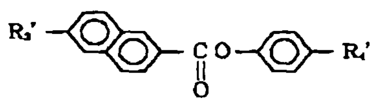
X3', X4': single bond,

$-\underset{\underset{O}{\|}}{C}O-$, $-O\underset{\underset{O}{\|}}{C}-$, $-CH_2O-$, $-OCH_2-$

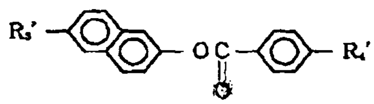
(0107)

(VIIa), (VIIb) are nominated as more preferred compound of (VII).

(0108)



(VII a)

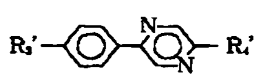


(VII b)

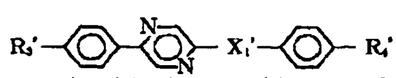
(0109)

(VIIIa), (VIIIb) are nominated as preferred compound of formula (VIII).

(0110)



(VIII a)

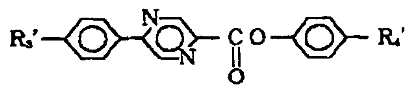


(VIII b)

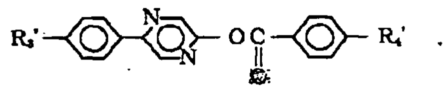
(0111)

(VIIIba), (VIIIbb) are nominated as more preferred compound of (VIIIb).

(0112)



(VIIIba)



(VIIIbb)

(0113)

Wherein, R3', R4' are straight chain form or branched chain form alkyl group of carbon number 1-18, and one or two or more $-CH_2-$ groups in the said alkyl group which are not adjacently positioned may be substituted by -CH halogen-. Moreover, one or two or more $-CH_2-$ groups except $-CH_2-$ group which is directly bonded with X1, X2 may be substituted by

(0114) (0115)

$$-O-,\quad -\underset{\underset{O}{\|}}{C}-,\quad -O\underset{\underset{O}{\|}}{C}-,\quad -\underset{\underset{O}{\|}}{C}O-,\quad -\overset{\overset{CN}{|}}{C}H-,\quad -\overset{\overset{CN}{|}}{C}CH_3-$$

(0116)

Wherein when R3' or R4' is alkyl halide wherein one CH2 group is substituted by -CH halogen-, R3' or R4' is not bonded with single bond with respect to ring.

(0117)

Preferably R3', R4' are the followings.

i) straight chain alkyl group of carbon number 1-15.

(0118)

ii)

$$-\!\left(CH_2\right)_p\overset{\overset{CH_3}{|}}{C}H-C_qH_{2q+1}$$

p: integer of 0-5, q: integer of 2-11, it may be optical active.

(0119)

iii)

$$-\!\left(CH_2\right)_r\overset{\overset{CH_3}{|}}{C}H\!\left(CH_2\right)_s-OC_tH_{2t+1}$$

r: integer of 0-6, s: integer of 0, 1, t: integer of 1-14, it may be optical active.

(0120)

iv)

$$-(CH_2)_u-\underset{*}{\overset{F}{\overset{|}{C}}}H-C_vH_{2v+1}$$

u: integer of 0, 1, v: integer of 1-16.

(0121)

v)

$$-\overset{CH_3}{\overset{|}{C}}H\underset{\underset{O}{\|}}{C}OC_wH_{2w+1}$$

w: integer of 1-15, it may be optical active.

(0122)

vi)

$$-(CH_2)_A\overset{CN}{\overset{|}{C}}HC_BH_{2B+1}$$

A: integer of 0-2, B: integer of 1-15, it may be optical active.

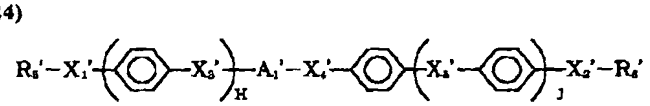
(0123)

vii)

$$-(CH_2)_C\underset{\underset{CH_3}{|}}{\overset{CN}{\overset{|}{C}}}-C_DH_{2D+1}$$

C: integer of 0-2, D: integer of 1-15, it may be optical active.

(0124)



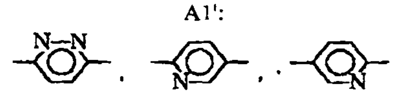
(IX)

H, J: 0 or 1, wherein H + J = 0 or 1

X1', X2': single bond,

$-\underset{\underset{O}{\|}}{C}O-$, $-O\underset{\underset{O}{\|}}{C}-$, $-O-$

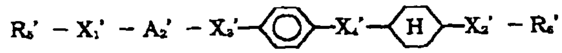
A1':



X3', X4': single bond,

$-\underset{\underset{O}{\|}}{C}O-$, $-O\underset{\underset{O}{\|}}{C}-$, $-CH_2O-$, $-OCH_2-$

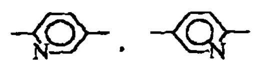
(0125)

 (X)

X1', X2': single bond,

$-\underset{\underset{O}{\|}}{C}O-$, $-O\underset{\underset{O}{\|}}{C}-$, $-O-$

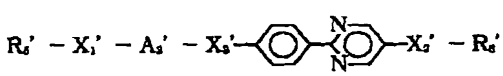
A2':



X3', X4': single bond,

$-\underset{\underset{O}{\|}}{C}O-$, $-O\underset{\underset{O}{\|}}{C}-$, $-CH_2O-$, $-OCH_2-$

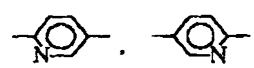
(0126)

 (XI)

X1', X2': single bond,

$-\underset{\underset{O}{\|}}{C}O-$, $-O\underset{\underset{O}{\|}}{C}-$, $-O-$

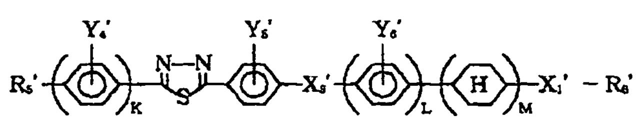
A3':



X3': single bond,

$-\underset{\underset{O}{\|}}{C}O-$, $-O\underset{\underset{O}{\|}}{C}-$, $-CH_2O-$, $-OCH_2-$

(0127)

 (XII)

K, L, M: 0 or 1, wherein K + L + M = 0 or 1

Y4', Y5', Y6': H or F

X1': single bond,

$-\underset{\underset{O}{\|}}{C}O-$, $-O\underset{\underset{O}{\|}}{C}-$, $-O-$

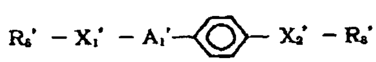
X3': single bond,

$-\underset{\underset{O}{\|}}{C}O-$, $-O\underset{\underset{O}{\|}}{C}-$, $-CH_2O-$, $-OCH_2-$

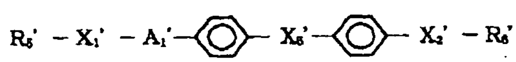
(0128)

(IXa)-(IXc) are nominated as preferred compounds of formula (IX).

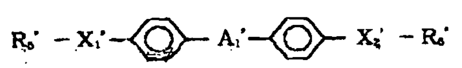
(0129)



(IX a)



(IX b)

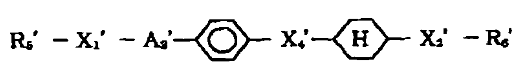


(IX c)

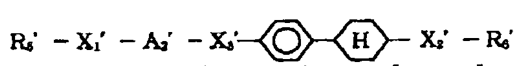
(0130)

(Xa), (Xb) are nominated as preferred compounds of formula (X).

(0131)



(X a)

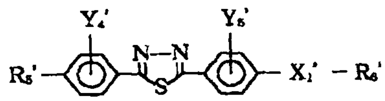


(X b)

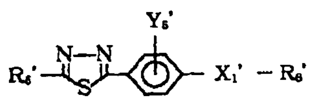
(0132)

(XIIa)-(XIId) are nominated as preferred compounds of formula (XII).

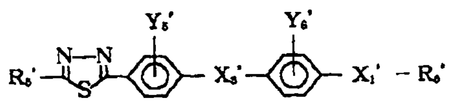
(0133)



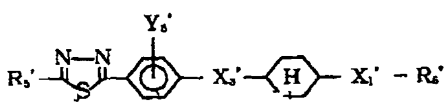
(XII a)



(XII b)



(XII c)

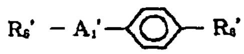


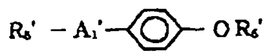
(XII d)

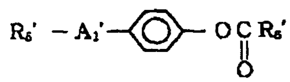
(0134)

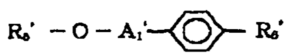
(IXaa)-(IXcc) are nominated as more preferred compounds of (IXa)-(IXc).

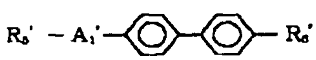
(0135)

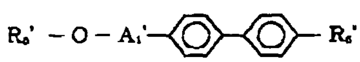

(IX aa)

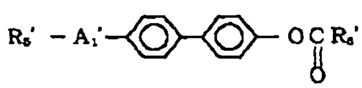

(IX ab)

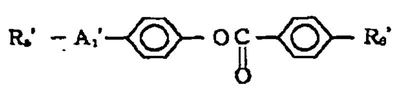

(IX ac)

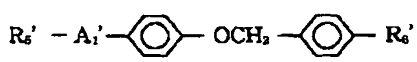

(IX ad)

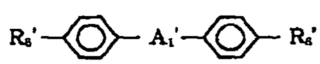

(IX ba)

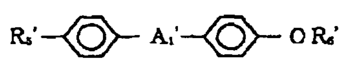

(IX bb)

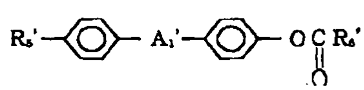

(IX bc)


(IX bd)


(IX be)


(IX ca)

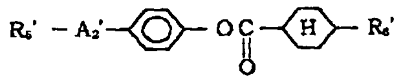

(IX cb)


(IX cc)

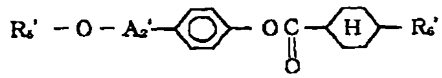
(0136)

(Xaa)-(Xbb) are nominated as more preferred compounds of (Xa), (Xb).

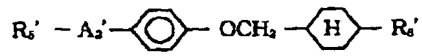
(0137)



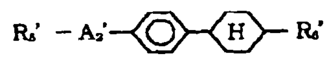
(X aa)



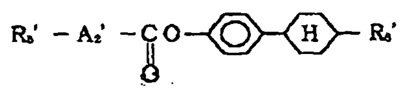
(X ab)



(X ac)



(X ba)

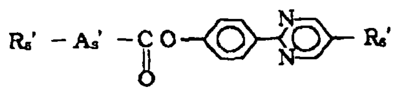


(X bb)

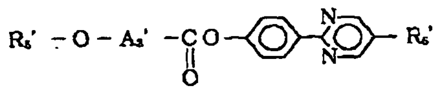
(0138)

(XIa)-(XIg) are nominated as more preferred compounds of (XI).

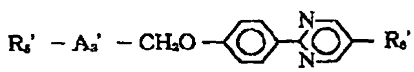
(0139)



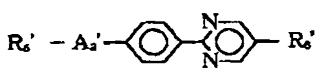
(XI a)



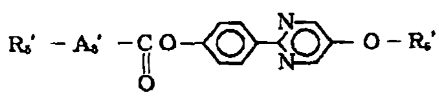
(XI b)



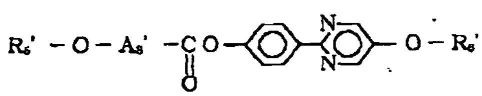
(XI c)



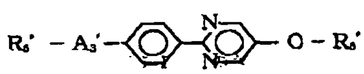
(XI d)



(XI e)



(XI f)

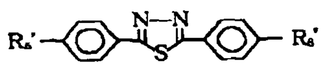


(XI g)

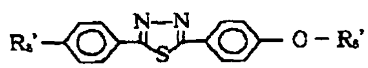
(0140)

(XIIaa)-(XIIdb) are nominated as more preferred compounds of (XIIa)-(XIId).

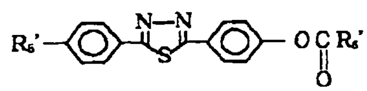
(0141)



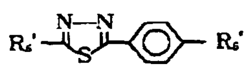
(XII aa)



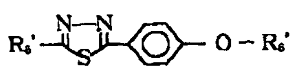
(XII ab)



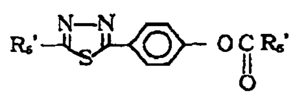
(XII ac)



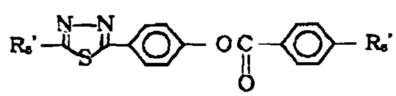
(XII ba)



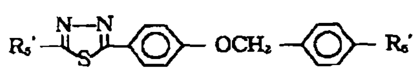
(XII bb)



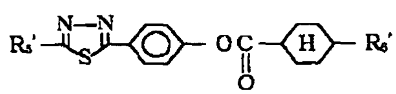
(XII bc)



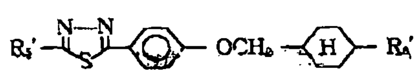
(XII ca)



(XII cb)



(XII da)



(XII db)

(0142)

Wherein, R5', R6' are straight chain form or branched chain form alkyl group of carbon number 1-18, and one or two or more $-CH_2-$ groups in the said alkyl group which are not adjacently positioned except $-CH_2-$ group which is directly bonded with X1, X2 may be substituted by

(0143)

$$-O-,\quad -\underset{\overset{\|}{O}}{C}-,\quad -O\underset{\overset{\|}{O}}{C}-,\quad -\underset{\overset{\|}{O}}{C}O-,\quad -\overset{\overset{CN}{|}}{C}H-,\quad -\overset{\overset{CN}{|}}{C}CH_3-$$

(0144)

Preferably R5', R6' are the followings.

i) straight chain alkyl group of carbon number 1-15.

(0145)

ii)

$$-(CH_2)_p\overset{\overset{CH_3}{|}}{C}H-C_qH_{2q+1}$$

p: integer of 0-5, q: integer of 2-11, it may be optical active.

(0146)

iii)

$$-(CH_2)_r\overset{\overset{CH_3}{|}}{C}H-(CH_2)_s-OC_tH_{2t+1}$$

r: integer of 0-6, s: integer of 0, 1, t: integer of 1-14, it may be optical active.

(0147)

iv)

$$-\overset{\overset{CH_3}{|}}{C}H\underset{\overset{\|}{O}}{C}OC_wH_{2w+1}$$

w: integer of 1-15, it may be optical active.

(0148)

v)

$$-(CH_2)_A\overset{\overset{CN}{|}}{C}HC_BH_{2B+1}$$

A: integer of 0-2, B: integer of 1-15, it may be optical active.

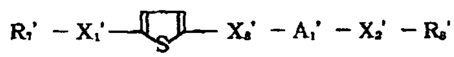
(0149)

vi)

$$-(CH_2)_C\underset{\underset{CH_3}{|}}{\overset{\overset{CN}{|}}{C}}-C_DH_{2D+1}$$

C: integer of 0-2, D: integer of 1-15, it may be optical active.

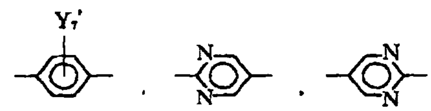
(0150)



(XIII)

A_1' : $-A_2'-$, $-A_2'-A_3'-$

A_2' , A_3' :



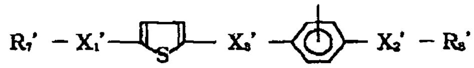
Y_7' : H , F

X_1' , X_2' : Single bond, $-\underset{\underset{O}{\|}}{C}O-$, $-O\underset{\underset{O}{\|}}{C}-$, $-O-$, $-\underset{\underset{O}{\|}}{C}-$

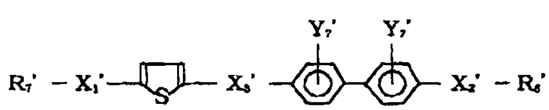
X_3' : $-\underset{\underset{O}{\|}}{C}O-$, $-CH_2O-$

(XIIIa)-(XIIIc) are nominated as preferred compounds of formula (XIII).

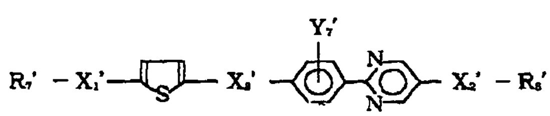
(0151)



(XIII a)



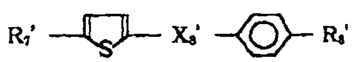
(XIII b)



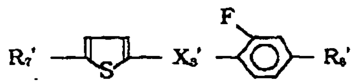
(XIII c)

(XIIIaa)-(XIIIch) are nominated as more preferred compounds of (XIIIa)-(XIIIc).

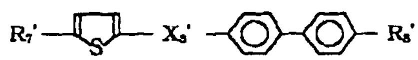
(0152)



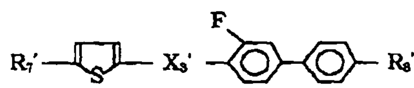
(XIIIa)



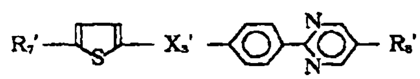
(XIIIab)



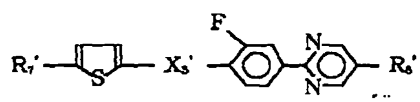
(XIIIba)



(XIIIbb)

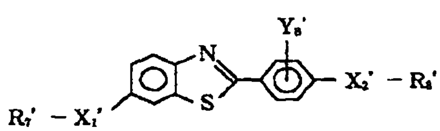


(XIIIca)



(XIIIcb)

(0153)



(XIV)

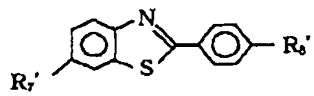
Y8': H, F

X1', X2': single bond,

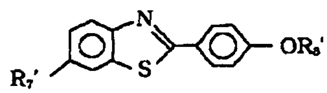
$-\underset{\underset{O}{\|}}{C}O-$, $-O\underset{\underset{O}{\|}}{C}-$, $-O-$, $-\underset{\underset{O}{\|}}{C}-$

(XIVa)-(XIVb) are nominated as preferred compounds of (XIV).

(0154)



(XIV a)



(XIV b)

(0155)

Wherein, R7', R8' are straight chain form or branched chain form alkyl group of carbon number 1-18, and one or two or more $-CH_2-$ groups in the said alkyl group which are not adjacently positioned may be substituted by -CH halogen-. Moreover, one or two or more $-CH_2-$ groups except $-CH_2-$ group which is directly bonded with X1, X2 may be substituted by

(0156)

$$-O-,\quad -\underset{\underset{O}{\|}}{C}-,\quad -O\underset{\underset{O}{\|}}{C}-,\quad -\underset{\underset{O}{\|}}{C}O-,$$

(0157)

Wherein when R7' or R8' is alkyl halide wherein one CH2 group is substituted by -CH halogen-, R7' or R8' is not bonded with single bond with respect to ring.

(0158)

Preferably R7', R8' are following i)-v).

i) straight chain alkyl group of carbon number 1-15.

(0159)

ii)

$$-(CH_2)_p-\overset{\overset{CH_3}{|}}{C}H-C_qH_{2q+1}$$

p: integer of 0-5, q: integer of 2-11, it may be optical active.

(0160)

iii)

$$-(CH_2)_r-\overset{\overset{CH_3}{|}}{C}H-(CH_2)_s-OC_tH_{2t+1}$$

r: integer of 0-6, s: integer of 0, 1, t: integer of 1-14, it may be optical active.

(0161)

iv)

$$-(CH_2)_u-\overset{F}{\overset{|}{\underset{*}{C}}}H-C_vH_{2v+1}$$

u: integer of 0, 1, v: integer of 1-16.

(0162)

v)

$$-\overset{CH_3}{\overset{|}{C}}H\underset{\underset{O}{\|}}{C}OC_wH_{2w+1}$$

w: integer of 1-15, it may be optical active.

(0163)

In accordance with this invention, it is desirable to make the proportion of liquid crystalline compound of this invention occupied in liquid crystal composition 1 wt.%-80 wt.%, preferably 1 wt.%-60 wt.%, and more preferably 1 wt.%-40 wt.%.

(0164)

Moreover, when two or more kinds of liquid crystalline compounds of this invention are used, it is desirable to make the proportion of the mixture of two or more kinds of liquid crystalline compounds of this invention occupied in the liquid crystal composition obtained by mixing 1 wt.%-80 wt.%, preferably 1 wt.%-60 wt.%, and more preferably 1 wt.%-40 wt.%.

(0165)

Next, the liquid crystal element of this invention is obtained by arranging the aforesaid liquid crystal composition between one pair of electrode base platess, and in particular, as for the liquid crystal layer which shows ferroelectricity in the ferroelectric liquid crystal element, it is preferable that the liquid crystal composition showing chiral smectic phase produced in aforesaid way is heated in vacuum to isotropic liquid temperature, this is encapsulated in element cell, and liquid crystal layer is formed by gradually cooling, and then it is returned to normal pressure.

(0166)

Figure 1 is a cross-sectional schematic diagram showing an example of liquid crystal element containing chiral smectic liquid crystal layer for explaining construction of the liquid crystal element using the ferroelectricity.

(0167)

In reference to Figure 1, the liquid crystal element is formed by arranging liquid crystal layer 1 showing chiral smectic phase between one pair of glass base plates 2 which have respectively been provided with transparent electrode 3 and insulating orientation controlling layer 4, and also by establishing the layer thickness thereof with spacer 5, and connection is made from the power supply 7 via lead wire 6 so that the voltage can be applied between one pair of transparent electrodes 3. Moreover, one pair of base plates 2 are sandwiched by one pair of cross-nicol polarizing plates 8, and light source 9 is arranged in outside of the one side thereof.

(0168)

In other words, the transparent electrode 3 made of thin film such as In2O3, SnO2 or ITO (Indium Tin Oxide) or the like is coated respectively on two sheets of glass base plates 2. Thin film of polymer such as polyimide is rubbed with gauze, acetate filled cloth or the like, and insulating orientation controlling layer 4 for arranging liquid crystal in the rubbing direction is formed thereon.

(0169)

Moreover, insulating orientation controlling layer 4 may be of two-layer structure wherein for example insulating layer of inorganic material such as silicon nitride, silicon nitride containing hydrogen, silicon carbide, silicon carbide containing hydrogen, silicon oxide, boron nitride, boron nitride containing hydrogen, cerium oxide, aluminum oxide, zirconium oxide, titanium oxide, magnesium fluoride or the like is formed, and thereon, layer of organic insulating material such as polyvinyl alcohol, polyimide, poly amide imide, polyesterimide, poly p-xylene, polyester, polycarbonate, polyvinylacetal, polyvinyl chloride, polyvinyl acetate, poly amide, polystyrene, cellulose resin, melamine resin, urea resin, acrylic resin, photoresist resin or the like is formed, and moreover it may be of a monolayer of inorganic substance insulating orientation controlling layer or organic substance insulating orientation controlling layer.

(0170)

If this insulating orientation controlling layer is of inorganic system, it can be formed by vapour deposition method or the like, and if it is of organic system, it can be formed by

hardening under prescribed hardening condition (for example with heating) the layer which is coated by spin coating method, dip coating method, screen printing, spray coating method, roll coating method and the like using solution dissolved organic insulating material or precursor solution thereof (in solution, 0.1-20 wt.%, preferably 0.2-10 wt.%).

(0171)

The layer thickness of insulating orientation controlling layer 4 is suitable usually 10Å-1 μm, preferably 10Å-3000Å, more preferably 10Å-1000Å.

(0172)

These two glass base plates 2 are held with an arbitrary interval by spacer 5. For example, there is a process that alumina beads, silica beads having fixed diameter, as spacer are sandwiched with two glass base plates, and the surrounding is sealed up using seal materials, for example epoxy system adhesion material. In addition, polymeric film and glass fibre may be used as spacer. Liquid crystal showing chiral smectic phase is enclosed between these two pieces of glass base plates. Liquid crystal layer 1 is generally set with the thickness of 0.5-20 μm, preferably 1-5 μm.

(0173)

The external power supply 7 is connected by lead wire to the transparent electrode 3. Moreover, one pair of polarizing plates 8 wherein the respective polarization axes are arranged for example in crossed-nicol state are attached on the external side of glass base plates 2. Example of Figure 1 is transmission type, and is provided with light source 9.

(0174)

Figure 2 is a diagram schematically drawing an example of cell in order to explain the driving of liquid crystal element using ferroelectricity. 21a and 21b are base plates (glass plates) coated with the transparent electrode respectively formed from the thin film such as In_2O_3, SnO_2 or ITO (Indium Tin Oxide) or the like, and liquid crystal of SmC* phase or SmH* phase are enclosed between the base plates so that the liquid crystal molecules layer 22 is oriented perpendicular to the glass surface. The bold lines 23 denote the liquid crystal molecules, and this liquid crystal molecules 23 has dipolar moment ($P_{\perp}$) 24 to the orthogonal-direction to the molecule thereof. When a voltage above the certain threshold value is applied between electrodes on the base plates 21a and 21b, spiral structure of liquid crystal molecules 23 is loosen, and thereby the liquid crystal molecules 23 can change the orientation direction so that the dipolar moment ($P_{\perp}$) 24 is all facing

the electric field direction. The shape of liquid crystal molecules 23 is long and narrow, and refractive index anisotropy is shown with longitudinal and short axis direction thereof, and accordingly, it is readily understandable that for example if crossed-nicol polarizers are put on top and under the glass surfaces, the liquid crystal optics modulation element whose optical characteristics are changed by electric potential polarity is formed.

(0175)

The liquid crystal cell preferably used for the optics modulation element in this invention can make the thickness thereof sufficiently thin (for example 10 μ or less). In this way, as the liquid crystal layer becomes thinner, the spiral structure of liquid crystal molecules is loosen even in a state not applying the electric field as shown in Figure 3, and the dipolar moment Pa or Pb faces either of upward (34a) or downward (34b) state. When a voltage above the certain threshold value having different polarity Ea or Eb is imparted to such cell by electric potential means 31a and 31b as shown in Figure 3, dipolar moment change the direction to upward 34a or downward 34b corresponding to the electric field vector of electric field Ea or Eb, and corresponding to this, the liquid crystal molecules are orientated to either one of the first stable state 33a or the second stable state 33b.

(0176)

There are two merits of using such ferroelectric liquid crystal molecule as optics modulation element, as described earlier. Firstly, the response rate thereof is extremely fast, and secondly, the orientation of liquid crystal molecules has bistability. As this second point is described by for example Figure 3, the liquid crystal molecules is orientated to the first stable state 33a, when electric field Ea is applied, however, this state is stable even the electric field is cut off. Moreover, if the oppositely directed electric field Eb is applied, the liquid crystal molecules is orientated to the second stable state 33b and the direction of molecule thereof is changed, but also this state is stable even the electric field is cut off. Moreover, unless the electric field Ea or Eb to be imparted exceeds a certain threshold value, the molecules are still maintained in each previous oriented state.

(0177)

The liquid crystal display apparatus is realized by using the liquid crystal element of this invention in display panel parts and by adopting communication synchronization means by SYNC signal and the data format comprising image information having scanning line address information as shown in Figure 4 and Figure 5.

(0178)

In Figures, symbols are respectively as follows.

101	Ferroelectric liquid crystal display apparatus
102	Graphics controller
103	Display panel
104	Scanning line drive circuit
105	Information line drive circuit
106	Decoder
107	Scanning signal development circuit
108	Shift register
109	Line memory
110	Information signal development circuit
111	Drive regulation circuit
112	GCPU
113	Host CPU
114	VRAM

(0179)

By using the liquid crystal element of this invention in display panel parts and by adopting communication synchronization means by SYNC signal and data format comprising image information having scanning line address information as shown in Figure 4 and Figure 5, the liquid crystal display apparatus is realized.

(0180)

The generation of image information is carried out at graphics controller 102 of main body apparatus side, and is transmitted to display panel 103 according to the signal transfer means shown in Figure 4 and Figure 5. Graphics controller 102 manages control and communication of image information between the host CPU113 and liquid crystal display apparatus 101 using CPU (Central Processing Unit, hereinafter abbreviated to GCPU112) and VRAM (Video Random Access Memory) 114 as central parts, and the control process of this invention is mainly realized on this graphics controller 102. Moreover, the light source is arranged on the back of the said display panel.

(0181)

Examples

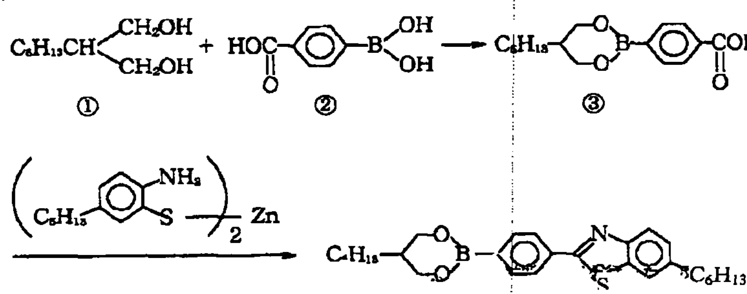
Hereinafter, this invention will be described further in greater detail on the basis of Examples, however, this invention is not limited to these Examples.

(0182)

Example 1

Production of 2-{4-(2-(5-hexyl-1,3,2-dioxaborinyl)) phenyl}-6-hexyl benzothiazole (I-13)

(0183)



(0184)

Step 1

Production of 2-hexyl-1,3-propanediol ([1])

Metallic sodium 11.5 g was dissolved in anhydrous ethanol 250 ml, and warmed to 50°C, and thereafter diethyl malonate ester 82.5 g (0.52 mol) was added dropwise. Thereafter it was added dropwise to hexyl bromide 82.5 g (0.5 mol), and heated under reflux for 6 hours. After completion of the reaction, the solvent was eliminated by distillation, and water was added, and extraction was carried out with diethyl ether. The obtained ether solution was dried with anhydrous magnesium sulphate, and next distillation was carried out, and 2-hexyl diethyl malonate ester 100 g was obtained. Among these, 2-hexyl diethyl malonate 95 g (0.4 mol) was dissolved in dried diethyl ether 40 ml, and it was added dropwise at 5°C to dried diethyl ether solution suspended lithium aluminium hydride 29 g (0.77 mol). Thereafter heating under reflux was carried out for five hours, and thereafter, it was cooled with ice, and water was added, and extraction was carried out with ethyl acetate. The obtained organic layer was dried using magnesium sulfate, and thereafter, it was purified by distillation, and the target substance of 52 g was obtained. b.p.125°C/3 mm Hg. Yield 68 %.

(0185)

Step 2

Production of 4-carboxy phenylboronic acid ([2])

134g of p-bromotoluene dissolved in dry tetrahydrofuran 300 ml was added dropwise to magnesium 20.5 g (0.79 mole) at room temperature, it was warmed to 60°C and stirred for two hours, and it was reacted, and Grignard Reagent was prepared. Separately, a solution dissolved trimethoxy borane 122 g (1.2 mole) in dry tetrahydrofuran 600 ml was prepared, and was cooled to -70°C, the Grignard Reagent obtained previously was added dropwise. It was kept at –70°C and was stirred for one hour, and thereafter, 420 ml of 10 % sulfuric acid was added, and hydrolysis was carried out. The insolubles were eliminated by filtration, and remaining solution was extracted with diethyl ether. The obtained organic layer was dried with anhydrous sodium sulphate, the solvent was eliminated by distillation, and p-tolyl boron acid of 79 g was obtained.

(0186)

From this, 68 g (0.5 mole) was dissolved in 10 % sodium hydroxide aqueous solution 400 ml, and water 2.9 l were added next. Potassium permanganate 166 g (1 mole) dissolved in water 5 l was gradually added to this solution, and the mixture was stirred at room temperature for 20 hours. Thereafter ethanol 200 ml was added, and it was warmed to 50°C and was stirred furthermore for one hour. On completion of the reaction, the formed manganese dioxide was removed by filtration, and the solvent was eliminated by distillation. Concentrated hydrochloric acid was added to this and was made acidic, the precipitated crystals were recovered by filtration, washed with water, thereafter, recrystallisation was carried out with water, and the target substance of 41 g was obtained. Yield 37 %.

(0187)

Step 3

Production of 4-{2-(5-hexyl-1,3,2-dioxaborinyl)} benzoic acid ([3])

2-hexyl-1,3-propanediol ([1]) 9.7 g (60 mmol) obtained in production Step 1 and 4-carboxy phenylboronic acid 10 g (60 mmol) obtained in Step 2 were heated under reflux in a reaction container fitted with azeotropic dewatering device for seven hours. On completion of the reaction, it was allowed to cool, the precipitated crystals were recovered by filtration, recrystallization was carried out from toluene, and it was purified. Yield 85 %.

(0188)

Step 4

Production of 2-{4-(2-(5-hexyl-1,3,2-dioxaborinyl)) phenyl }-6-hexyl benzothiazole (I-13)

4-{2-(5-hexyl-1, 3,2-dioxaborinyl)} benzoic acid ([3]) 1.2 g (4 mmol) obtained in production Step 3 was dissolved in thionyl chloride 2.5 ml, and one drop of dimethylformamide was added to this, and heating under reflux was carried out for four hours. After completion of the reaction, excess thionyl chloride was eliminated by distillation, and acid chloride was obtained. 5-hexyl-2-aminothiol hydrochloride 0.96 g (2.0 mmol) was added to this acid chloride and was stirred at 200°C for 30 minutes. On completion of the reaction, it was allowed to cool, water was added, and extraction with toluene was carried out. The obtained organic layer was dried with anhydrous sodium sulphate, and next the solvent was eliminated by distillation, and it was purified by silica gel column chromatography (mobile phase = toluene). Furthermore, recrystallization was further carried out with ethyl acetate, and the target substance of 0.5 g was obtained. Yield 28 %.

Phase transition temperature (°C).

(0189)

(equation 2).

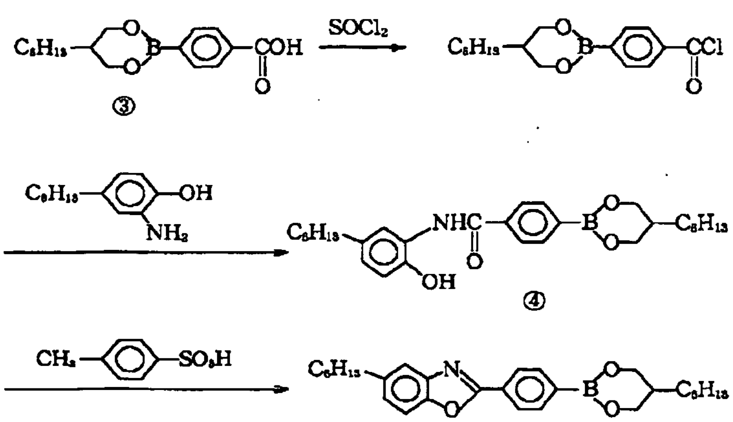
$$\text{Cryst.} \underset{75}{\overset{109}{\longleftrightarrow}} \text{SA} \underset{76}{\overset{137}{\longleftrightarrow}} \text{N} \underset{169}{\overset{170}{\longleftrightarrow}} \text{Iso}$$

(0190)

Example 2

Production of 5-hexyl-2-{4-(5-hexyl-1,3,2-dioxaborinyl) phenyl} benzo oxazole (I-11).

(0191)



(0192)

Step 1

Production of N-(2-hydroxy-5-hexyl phenyl)-4'-(5-hexyl-1,3,2-dioxaborinyl) benzamide ([4])

4-(5-hexyl-1,3,2-dioxaborinyl) benzoic acid ([3]) 1 g (3.5 mmol) obtained in Production Example 1 Step 3 was dissolved in thionyl chloride 2 ml, and one drop of dimethylformamide was added, and heating under reflux was carried out for four hours. After completion of the reaction, excess thionyl chloride was eliminated by distillation, and acid chloride was obtained. This acid chloride and 5-hexyl-2-hydroxyaniline 0.67 g (3.5 mmol) were dissolved in dioxane 20 ml, and thereafter pyridine 1.2 ml (15 mmol) was added, and it was warmed to 80-90°C, and it was stirred for 20 minutes. On completion of the reaction, product was injected into water, thereby precipitated crystals were recovered by filtration, and purification was performed by recrystallization with methanol. The target substance was obtained in yielded quantity of 1.2 g, yield 73 %.

(0193)

Step 2

Production of 5-hexyl-2-{4-(5-hexyl-1,3,2-dioxaborinyl) phenylbenzoxazole (I-11)

N-(2-hydroxy-5-hexyl phenyl)-4'-(5-hexyl-1,3,2-dioxaborinyl) benzamide ([4]) 1.1 g obtained in production Step 1 and p-toluenesulfonic acid 0.12 g were dissolved in 1,2-dichlorobenzene 20 ml, and it was warmed to 190-202°C, and it was stirred for 50 minutes. On completion of the reaction, the solvent was eliminated by distillation, and it was purified by silica gel column chromatography (mobile phase = toluene / ethyl acetate = 100/1) and also it was recrystallised from toluene / methanol mixture medium, and the target substance 0.93 g was obtained. Yield 88 %.

Phase transition temperature (°C).

(0194)

(equation 3).

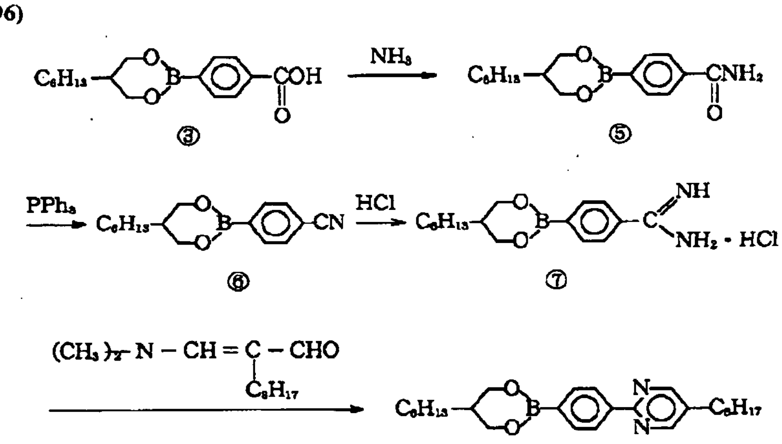
$$\begin{tikzcd}[column sep=large] \mathrm{Cryst.} \arrow[r, shift left, "83"] & \mathrm{S3} \arrow[l, shift left, "55"] \arrow[r, shift left, "90"] & \mathrm{SA} \arrow[l, shift left, "89"] \arrow[rr, "140"] & & \mathrm{Iso} \\ & & & \mathrm{N} \arrow[ul, "139"] \arrow[ur, "141"'] & \end{tikzcd}$$

(0195)

Example 3

Production of 5-hexyl-2-{4-(5-octyl-2-pyrimidyl) phenyl}-1,3,2-dioxaborinane (I-81).

(0196)



(I – 81)

(0197)

Step 1

Production of 2-(4-carbamoyl phenyl)-5-hexyl-1,3,2-dioxaborinane ([5])

4-(5-hexyl-1,3,2-dioxaborinyl) benzoic acid ([3]) 5 g (17 mmol) obtained in Step 3 of Production Example 1 was dissolved in thionyl chloride 10 ml, and one drop of dimethylformamide was added, and heating under reflux was carried out for four hours. On completion of the reaction, excess thionyl chloride was eliminated by distillation, and acid chloride was obtained. 28 % ammonia water 45 ml were cooled to around 0°C with ice-sodium chloride bath, the aforesiad acid chloride was dissolved with stirring in tetrahydrofuran 90 ml, and it were added dropwise a little at a time. On completion of the dropwise addition, the mixture was stirred at room temperature for four hours 30 minutes. Thereafter, the reactant was discharged into water 200 ml, the precipitated crystals were recovered by filtration, it was washed with water, thereafter, recrystallisation was carried out with acetone, and the target substance of 2.7 g was obtained. Yield 54 %.

(0198)

Step 2

Production of 2-(4-cyanophenyl)-5-hexyl-1,3,2-dioxaborinane ([6]).

Triphenylphosphine 4.8 g (18 mmol) was dissolved in carbon tetrachloride 14 ml, and it were added under state suspended 2-(4-carbamoyl phenyl)-5-hexyl-1, 3,2-dioxaborinane (black solid square) 2.7 g obtained in Step 1 to a place stirred at room temperature in tetrahydrofuran 10 ml, and it was warmed to 50-52°C, and it was stirred for three hours. On completion of the reaction, the reactant was cooled with iced water, the insolubles were removed by filtration, the solvent was eliminated by distillation, and it was purified

by silica gel column chromatography (mobile phase = toluene / ethyl acetate = 100/1) and 2.1 g target substance was obtained. Yield 84 %

(0199)

Step 3

Production of 4-{2-(5-hexyl-1,3,2-dioxaborinyl)} benzamidine hydrochloride ([7])

2-(4-cyanophenyl)-5-hexyl-1,3,2-dioxaborinane ([6]) 2 g obtained in production Step 2 and ethanol 0.4 g were dissolved in 20ml of chloroform, and it was stirred for ten minutes while blowing hydrochloric acid gas under cooling with ice-sodium chloride bath. On completion of the reaction, 5M sodium hydroxide aqueous solution 100 ml wsa added, the precipitated crystals were recovered by filtration, and ammonium chloride 0.4 g (7.7 mmol), ethanol 6 ml and water 6 ml were added, and the mixture was heated to 80°C and stirred for 30 minutes, it was allowed to cool, and the precipitated crystals were recrystallised from acetone, and it was purified. The target substance was obtained in yield quantity of 0.73 g, yield 31 %.

(0200)

Step 4

Production of 5-hexyl-2-(4-(5-octyl-2-pyrimidyl) phenyl)-1,3,2-dioxaborinane (I-81)

4-(2-(5-hexyl-1,3,2-dioxaborinyl)) benzamidine hydrochloride ([7]) 0.35 g (1.1 mmol) obtained in production Step 3 and beta-dimethylamino-alpha-octyl acrolein 0.23 g (1.1 mmol) were dissolved in methanol 5 ml, and it was stirred for nine hours, thereafter, the reactant was discharged into iced water 60 ml and extraction was carried out with toluene and ethyl acetate. The obtained organic layer was dried with anhydrous magnesium sulphate, thereafter the solvent was eliminated by distillation, it was purified by silica gel column chromatography (mobile phase = toluene / ethyl acetate = 100/1), recrystallisation was carried out with toluene / methanol mixture medium, and the target substance of 0.22 g was obtained. Yield 47 %
phase transition temperature (°C).

(0201)

(equation 4).

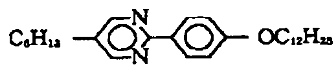
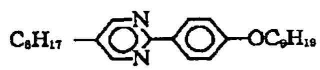
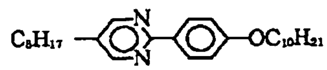
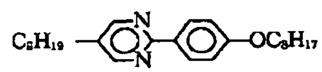
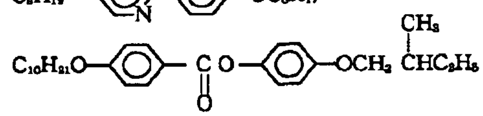
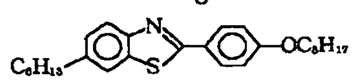
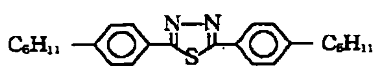
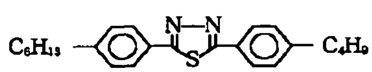
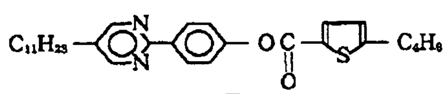
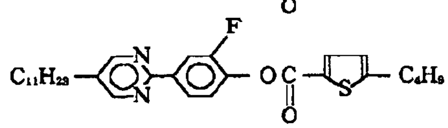
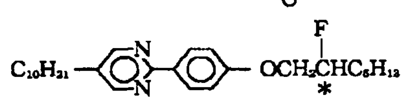
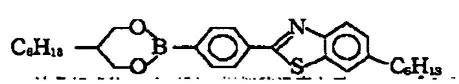
$$\text{Cryst.} \underset{12}{\overset{14}{\longleftrightarrow}} \text{S3} \underset{134}{\overset{137}{\longleftrightarrow}} \text{Iso}$$

(0202)

Example 4.

Following compounds including the representative compound (I-13) produced in Example 1 were mixed by following pts.wt, and liquid crystal composition A was made.

(0203)

Structural formula		pts.wt.
		4.0
		8.0
		8.0
		4.0
		16.0
		20.0
		5.0
		5.0
		6.7
		3.3
		10.0
	(I − 13)	10.0

(0204)

This liquid crystal composition A denotes the following phase transition temperature.

(0205)

(equation 5).

$$\mathrm{Cry} \xrightarrow{-21} S_C{*} \xrightarrow{63} S_A \xrightarrow{74} \mathrm{Ch} \xrightarrow{87} \mathrm{Iso}$$

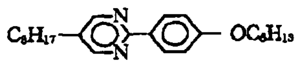
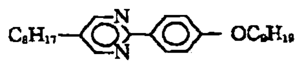
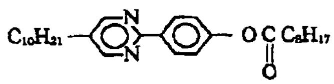
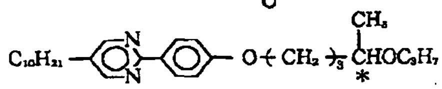
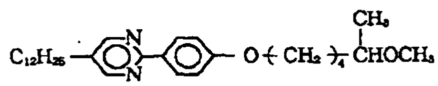
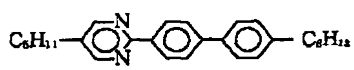
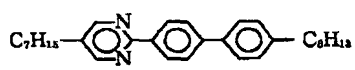
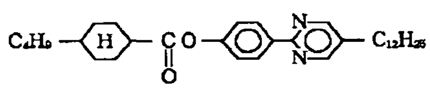
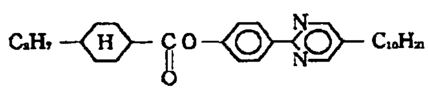
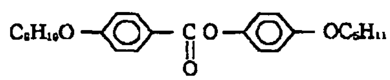
(°C)

(0206)

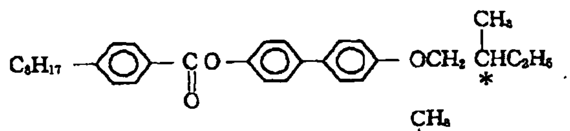
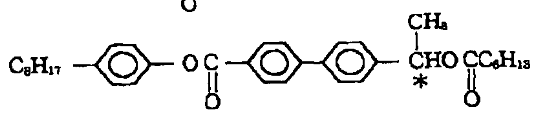
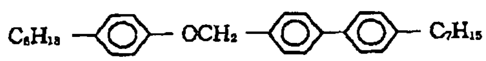
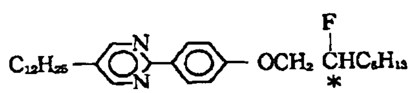
Example 5.

Following compounds were mixed by the following pts.wt, and liquid crystal composition B was made.

(0207)

Structural formula	pts.wt.
	10
	5
	7
	7
	6
	5
	5
	8
	8
	20

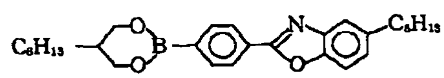
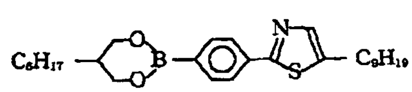
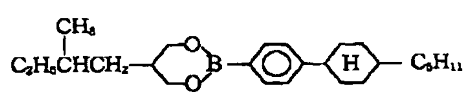
(0208)

Structural formula	pts.wt.
	5
	5
	6
	3

(0209)

Furthermore, following representative compounds were mixed by each pts.wt. shown below with respect to this liquid crystal composition B, and liquid crystal composition C was made.

(0210)

Representative comp. No.	Structural formula	pts.wt.
I - 11		3
I - 17		4
I - 27		2
	B	91

(0211)

Two sheets of glass plate of 0.7 mm thicks were prepared, and ITO membrane was formed on each glass plate, and electric potential electrode was made, and also SiO2 was vaporised thereon, and insulating layer was formed. Silane coupling agent [KBM-602

made by Shin-Etsu Chemicals (KK)] 0.2 % isopropyl alcohol solution was applied on glass plate with a spinner of number of rotations 2000 r.p.m for 15 seconds, and surface treatment was carried out. Thereafter baking treatment was carried out at 120°C for 20 minutes.

(0212)

Polyimide resin precursor (SP-510 made by Toray Co. Ltd.) 1.5 % dimethylacetamide solution was applied on furthermore the surface treated and ITO membrane formed glass plate with a spinner of number of rotations 2000 r.p.m for 15 seconds. After the film formation, the It is formed into a film, 300°C heat condensation baking treatment was carried out for 60 minutes. During this time, the film thickness of coated film was about 250 Å.

(0213)

Rubbing treatment with acetate filled cloth was carried out on this post-baking film, thereafter, it was washed with isopropyl alcohol liquid, then alumina beads of average particle diameter 2 micrometer was scattered on one of the glass plate, thereafter respective rubbing treatment axis was arranged in parallel to each other, the glass plates were laminated using adhesive sealing agent [Lixon bond made by Chisso (KK)], it was heated and dried at 100°C for 60 minutes, and cell was formed.

(0214)

Liquid crystal composition C was injected into this cell under isotropy liquid state, and ferroelectric liquid crystal element was made by gradually cooling to 25°C at 20°C/h from the isotropic phase. The cell thickness of this cell was measured by Berek compensator to be about 2 micrometer.

(0215)

Using this ferroelectric liquid crystal element, the optical response under the crossed nicol (quantity of transmitted beam change 0-90 %) was detected by an electric potential size Ps of spontaneous polarization and peak-to-peak voltage Vpp = 20V, and the response rate (hereinafter, abbreviated as optical response rate) was measured. The measurement result thereof is shown below.

(0216)

Table 1

	10°C	25°C	40°C
Response rate	525 μ sec	262 μ sec	143 μ sec.

(0217)

Comparative Example 1

Ferroelectric liquid crystal element was made by completely the same process as in Example 5 except that the liquid crystal composition B mixed in Example 5 was injected into cell, and optical response rate was measured. The measurement result thereof is shown below.

(0218)

Table 2

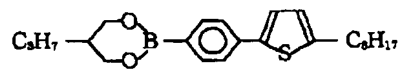
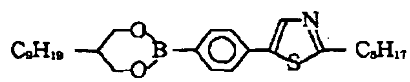
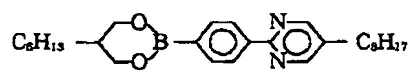
	10°C	25°C	40°C
Response rate	653 μ sec	317 μ sec	159 μ sec.

(0219)

Example 6.

Representative compounds shown below were mixed by each pts.wt. shown below instead of representative compounds I-11, 17, 27 used in Example 5, and liquid crystal composition D was made.

(0220)

Representative comp. No.	Structural formula	pts.wt.
I − 7		2
I − 20		4
I − 81		4
	B	**90**

(0221)

Ferroelectric liquid crystal element was made by completely the same process as in Example 5 except that this liquid crystal composition was used, and optical response rate was measured by same process as in Example 5. The measurement result thereof is shown below.

(0222)

Table 3

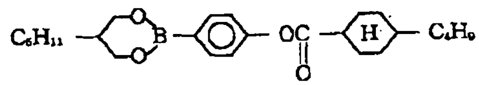
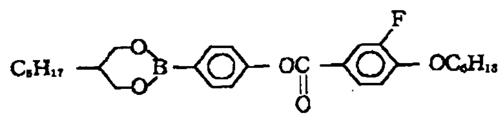
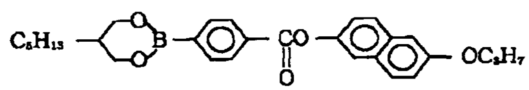
	10°C	25°C	40°C
Response rate	536 μ sec	266 μ sec	148 μ sec.

(0223)

Example 7.

Representative compounds shown below were mixed by each pts.wt. shown below instead of representative compounds I-11, 17, 27 used in Example 5, and liquid crystal composition E was made.

(0224)

Representative comp. No.	Structural formula	pts.wt.
I − 58		4
I − 61		3
I − 70		2
	B	91

(0225)

Ferroelectric liquid crystal element was made by completely the same process as in Example 5 except that this liquid crystal composition was used, and optical response rate was measured by same process as in Example 5. Measurement the results are shown below.

(0226)

Table 4

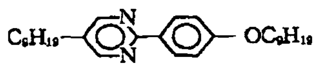
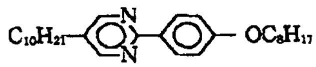
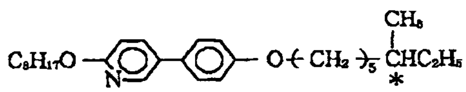
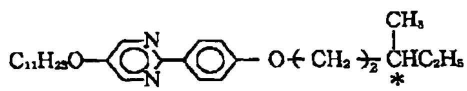
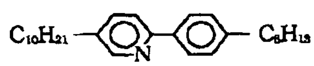
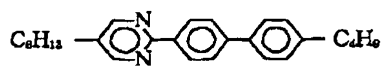
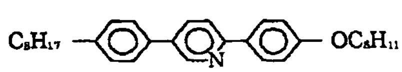
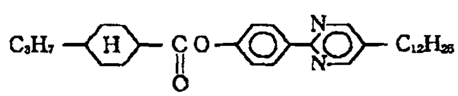
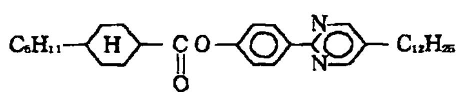
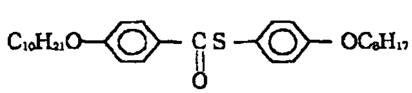
	10°C	25°C	40°C
Response rate	579 μ sec	290 μ sec	152 μ sec.

(0227)

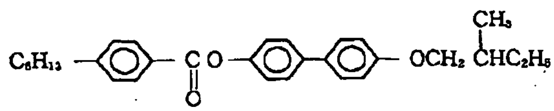
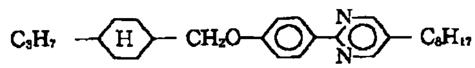
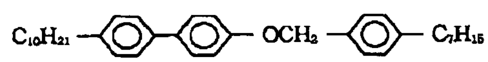
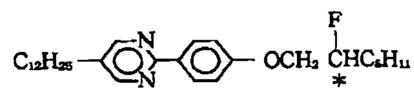
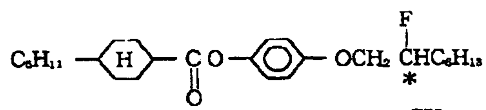
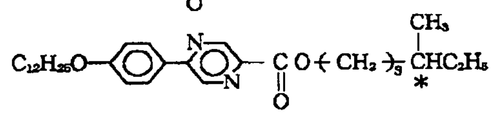
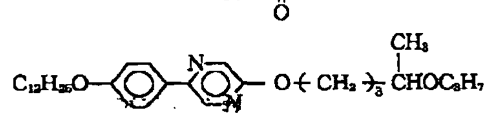
Example 8.

Following compounds were mixed by the following pts.wt, and liquid crystal composition F was made.

(0228)

Structural formula	pts.wt.
	6
	6
	7
	14
	8
	4
	2
	10
	5
	10

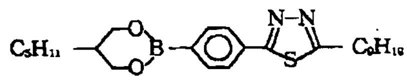
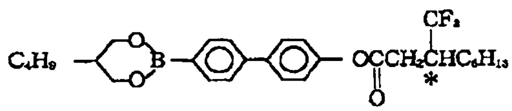
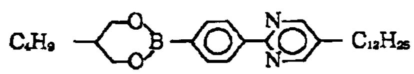
(0229)

Structural formula	pts.wt.
	7
	7
	5
	2
	2
	2
	3

(0230)

Furthermore, following representative compounds were mixed by each pts.wt. shown below with respect to this liquid crystal composition F, and liquid crystal composition G was made.

(0231)

Representative comp. No.	Structural formula	pts.wt.
I - 15		3
I - 50		2
I - 83		3
	F	92

(0232)

Ferroelectric liquid crystal element was made by completely the same process as in Example 5 except that liquid crystal composition G was injected into cell, and optical response rate was measured. The measurement result thereof is shown below.

(0233)

Table 5

	10°C	25°C	40°C
Response rate	567 μ sec	299 μ sec	162 μ sec.

(0234)

Comparative Example 2

Ferroelectric liquid crystal element was made by completely the same process as in Example 5 except that liquid crystal composition F mixed in Example 8 was injected into cell, and optical response rate was measured. The measurement result thereof is shown below.

(0235)

Table 6

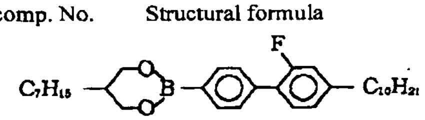
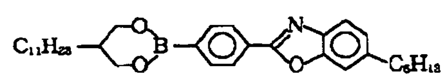
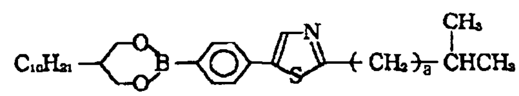
	10°C	25°C	40°C
Response rate	668 μ sec	340 μ sec	182 μ sec.

(0236)

Example 9.

Representative compounds shown below were mixed by each pts.wt. shown below instead of representative compounds I-15, 50, 83 used with Example 8, and liquid crystal composition H was made.

(0237)

Representative comp. No.	Structural formula	pts.wt.
I – 4		2
I – 9		3
I – 40		3
	F	92

(0238)

Ferroelectric liquid crystal element was made by completely the same process as in Example 5 except that this liquid crystal composition was used, and optical response rate was measured by same process as in Example 5. The measurement result thereof is shown below.

(0239)

Table 7

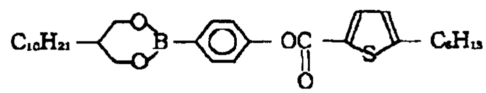
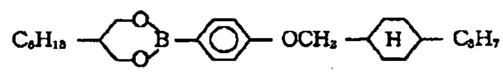
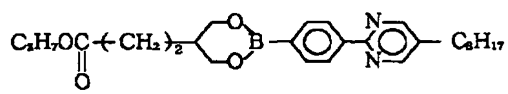
	10°C	25°C	40°C
Response rate	594 μ sec	313 μ sec	168 μ sec.

(0240)

Example 10.

Representative compounds shown below were mixed by each pts.wt. shown below instead of representative compounds I-15, 50, 83 used in Example 8, and liquid crystal composition J was made.

(0241)

Representative comp. No.	Structural formula	pts.wt.
I－63		4
I－64		4
I－90		2
	F	90

(0242)

Ferroelectric liquid crystal element was made by completely the same process as in Example 5 except that this liquid crystal composition was used, and optical response rate was measured by same process as in Example 5. The measurement result thereof is shown below.

(0243)

Table 8

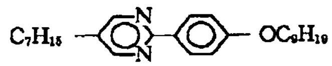
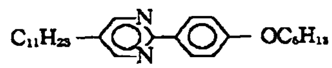
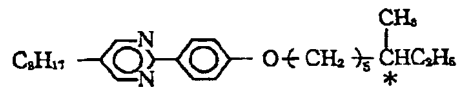
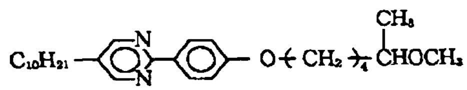
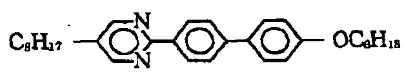
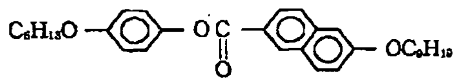
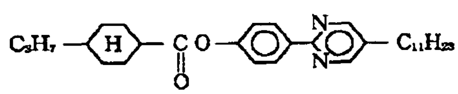
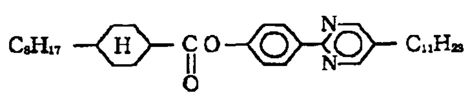
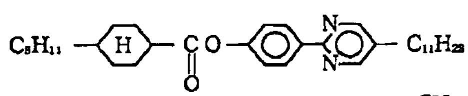
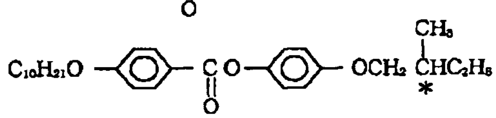
	10°C	25°C	40°C
Response rate	623 μ sec	322 μ sec	173 μ sec.

(0244)

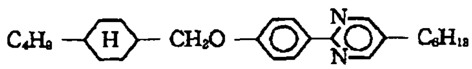
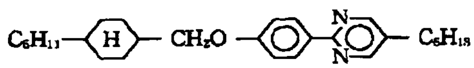
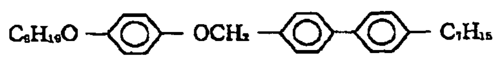
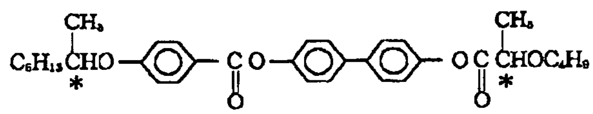
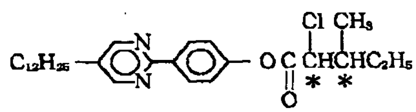
Example 11.

Following compounds were mixed by the following pts.wt, and liquid crystal composition K was made.

(0245)

Structural formula	pts.wt.
	12
	10
	10
	3
	8
	4
	6
	2
	8
	15

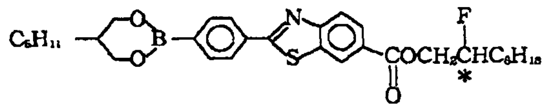
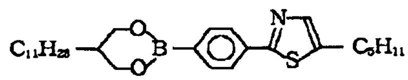
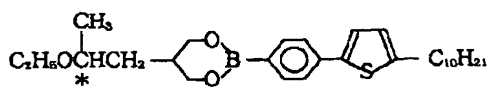
(0246)

Structural formula	pts.wt.
	7
	7
	4
	2
	2

(0247)

Furthermore, following representative compounds were mixed by each pts.wt. shown below with respect to this liquid crystal composition K, and liquid crystal composition L was made.

(0248)

Representative comp. No.	Structural formula	pts.wt.
I - 54		2
I - 37		4
I - 42		2
	K	92

(0249)

Ferroelectric liquid crystal element was made by completely the same process as in Example 5 except that liquid crystal composition L was injected into cell, and optical response rate was measured. The measurement result thereof is shown below.

(0250)

Table 9

	10°C	25°C	40°C
Response rate	648 μ sec	325 μ sec	173 μ sec.

(0251)

Comparative Example 3

Ferroelectric liquid crystal element was made by completely the same process as in Example 5 except that liquid crystal composition K mixed in Example 11 was injected into cell, and optical response rate was measured. The measurement result thereof is shown below.

(0252)

Table 10

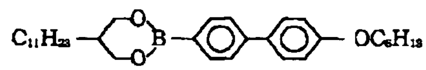
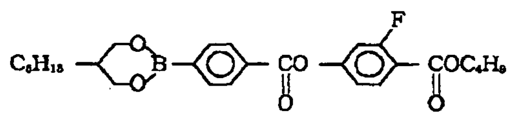
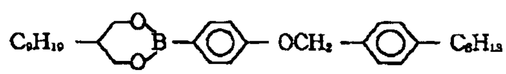
	10°C	25°C	40°C
Response rate	784 μ sec	373 μ sec	197 μ sec.

(0253)

Example 12.

Representative compounds shown below were mixed by each pts.wt. shown below instead of representative compounds I-54, 37, 42 used in Example 11, and liquid crystal composition M was made.

(0254)

Representative comp. No.	Structural formula	pts.wt.
I − 43		3
I − 74		3
I − 65		3
	K	91

(0255)

Ferroelectric liquid crystal element was made by completely the same process as in Example 5 except that this liquid crystal composition was used, and optical response rate was measured by same process as in Example 5. The measurement result thereof is shown below.

(0256)

Table 11

	10°C	25°C	40°C
Response rate	688 μ sec	340 μ sec	180 μ sec.

(0257)

As may be clear from Examples 4-12 that the ferroelectric liquid crystal elements containing liquid crystal composition C, D, E, G, H, J and L, M in accordance with this invention showed improved action character and high speed responsivity at low

temperature, and moreover, the temperature dependency of response rate was also reduced.

(0258)

Example 13.

Ferroelectric liquid crystal element was produced by completely the same process using polyvinyl alcohol resin (PUA-117 made by Kuraray (KK)) 2 % aqueous solution instead of polyimide resin precursor 1.5 % dimethylacetamide solution used with Example 5, and optical response rate was measured by same process as in Example 5. The measurement result thereof is shown below.

(0259)

Table 12

	10°C	25°C	40°C
Response rate	558 μ sec	296 μ sec	160 μ sec.

(0260)

Example 14.

Ferroelectric liquid crystal element was made by completely the same process as in Example 5 except that orientation controlling layer was made only with polyimide resin without using SiO2 which was used with Example 5, and optical response rate was measured by same process as in Example 5. The measurement result thereof is shown below.

(0261)

Table 13

	10°C	25°C	40°C
Response rate	550 μ sec	292 μ sec	158 μ sec.

(0262)

As may be clear from Example 13 and 14 that even when the element composition was changed, the element containing ferroelectric liquid crystal composition in accordance with this invention showed marked improvement of low temperature action character and also reduced temperature dependency of response rate in the same way as in Example 5.

(0263)

Advantages Afforded by this Invention

The compounds of this invention, if displaying chiral smectic phase by themselves, comprise the materials that can be effectively applied to element using ferroelectricity. Moreover, when the liquid crystal composition containing the compound of this invention displays chiral smectic phase, the element containing the said liquid crystal composition can be driven using the ferroelectricity displayed by the said liquid crystal composition. The ferroelectric liquid crystal elements which can be used in this way have good switching character, and can be made into liquid crystal elements with improved low temperature action character and liquid crystal elements with reduced temperature dependency of response rate.

(0264)

Moreover, the visual display unit that combined the liquid crystal molecule of this invention as display element with light source and drive circuit makes a good device.

Brief Description of the Figures

Figure 1

Figure 1 comprises a cross-sectional schematic diagram of an example of liquid crystal element using the liquid crystal that displays chiral smectic phase.

Figure 2

Figure 2 comprises an oblique view showing representation of an example of element cell for the explanation of action of the liquid crystal element using the ferroelectricity of the liquid crystal.

Figure 3

Figure 3 comprises an oblique view showing representation of an example of element cell for the explanation of action of liquid crystal molecule using the ferroelectricity of the liquid crystal.

Figure 4

Figure 4 comprises a block constitution diagram showing the liquid crystal display apparatus containing the liquid crystal molecule using ferroelectricity and graphics controller.

Figure 5

Figure 5 comprises a image information communication timing chart between the liquid crystal display apparatus and graphics controller.

Key to Symbols

1. The liquid crystal layer having chiral smectic phase
2. Glass base plate
3. Transparent electrode
4. Insulating orientation controlling layer
5. Spacer
6. Lead wire
7. A power supply
8. Polarizing plate
9. Light source

I_0. Incident beam

I. Transmitted beam

21a. Base plate

21b. Base plate

22. Liquid crystal layer having chiral smectic phase
23. Liquid crystal molecules
24. Dipolar moment ($P_{\perp}$)

31a. Voltage applying means

31b. Voltage applying means

33a. First stable state

33b. Second stable state

34a. Upward dipolar moment

34b. Downward dipolar moment

Ea. Upward electric field

Eb. Downward electric field

101. Ferroelectric liquid crystal display apparatus
102. Graphics controller
103. Display panel
104. Scanning beam drive circuit
105. Information line drive circuit
106. Decoder
107. Scanning signal generating circuit
108. Shift register
109. Line memory

110. Information signal generating circuit
111. Drive control circuit
112. GCPU
113. Host CPU
114. VRAM.

Figure 1

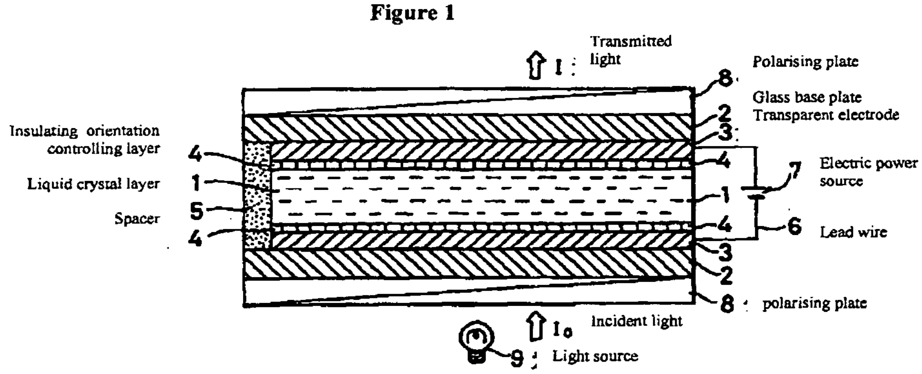


Figure 2

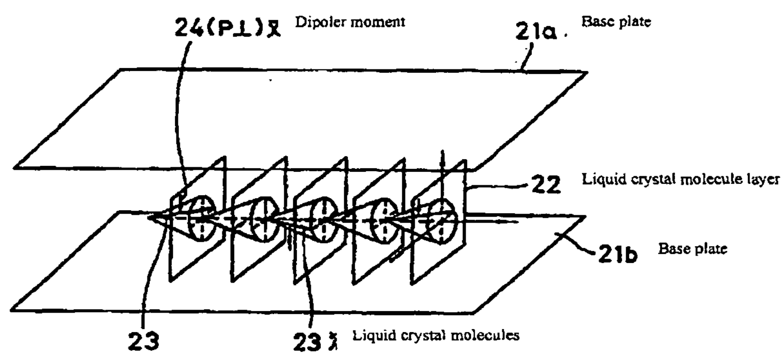


Figure 3

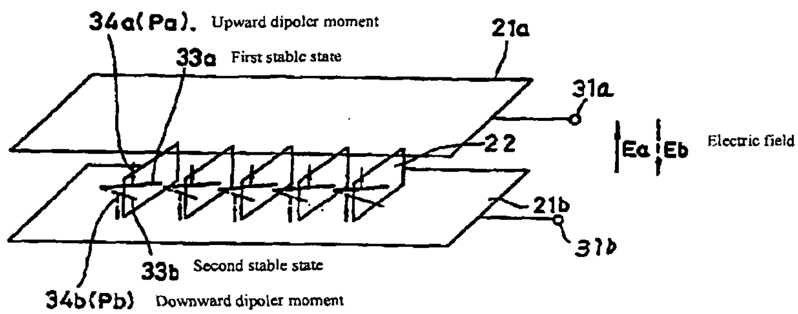
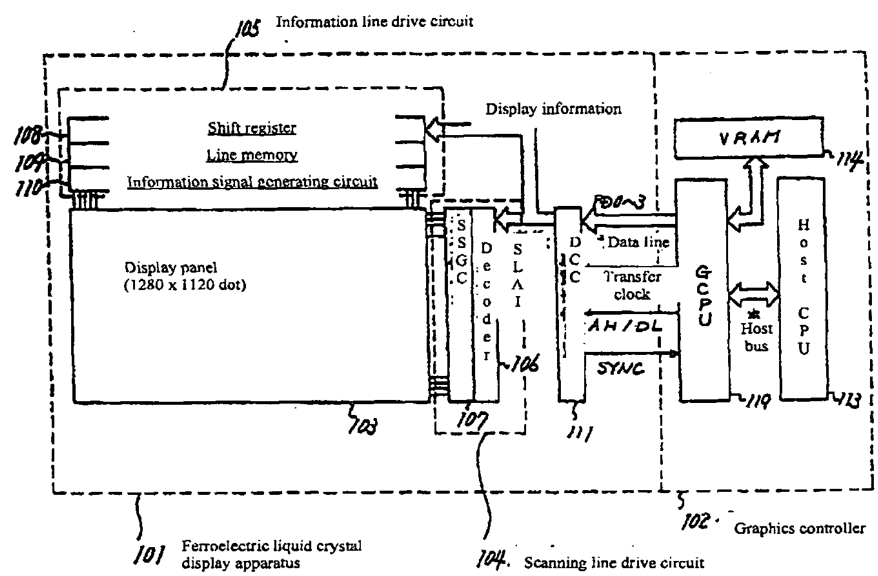
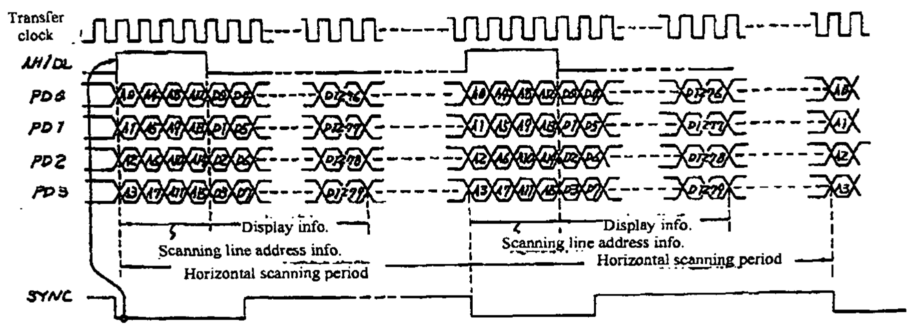


Figure 4



SSGC: Scanning signal generating circuit, SLAI: Scanning line address information, DCC: Drive control circuit

Figure 5


Transfer clock
AH/DL
PD0
PD1
PD2
PD3
Display info.
Scanning line address info.
Horizontal scanning period
Display info.
Scanning line address info.
Horizontal scanning period
SYNC

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